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MEDICAL ELECTRICITY.

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A TREATISE

ON

MEDICAL ELECTRICITY

THEORETICAL AND PRACTICAL

AND ITS USE IN THE TREATMENT OF

PARALYSIS, NEURALGIA, AND OTHER DISEASES

BY

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PHYSICIAN TO THE INFIRMARY FOR EPILEPSY AND PARALYSIS.

'That which forms the invisible but living weapon of the electric eel; that which liberated by the contact of moist dissimilar particles circulates through all the organs of animals and plants; that which flashing from the thunder-cloud illumines the wide skyey canopy; that which draws iron to iron, and directs the silent recurring march of the guiding needle;—all, like the several hues of the divided ray of light, flow from one source, and all blend again together in one perpetual force, which is diffused everywhere.'

Alexander von Humboldt, *Aspects of Nature.*

THIRD EDITION, ENLARGED AND REVISED.

WITH 147 ILLUSTRATIONS.

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PREFACE

TO

THE THIRD EDITION.

THE last edition of this Treatise having become exhausted, I have carefully revised the book, and incorporated with it the results of all the recent work done in this department of science. Not only has a large amount of new matter been added, but the pruning-scissors have been freely used fo eliminating what was no longer required, either in disposing of now antiquated theories, or in proving facts which have since then become self-evident. The quantity of new matter in the present edition is therefore much more considerable than would appear merely from the increased size and number of pages. The physiological part of the subject has been carefully brought up to the level of the day; the chapter on diagnosis has been amplified, special attention having been drawn to the value of faradisation in detecting malingerers, and as a test for death soon after its occurrence; the clinical chapter has also been rendered fuller, and enlarged experience has enabled me to answer the numerous questions connected with the therapeutical use of electricity in a more precise manner.

The electrolytic treatment of tumours has been much practised in the interval between the appearance of the second and third editions; and although this particular branch of our subject appears to be still in its infancy, yet indications are not wanting that it will soon occupy a far more important place in therapeutics than many eminent surgeons were willing to believe, when I first suggested this plan of treatment six years ago.

A large number of new illustrations has been added, which it is hoped will render the text easier of comprehension.

The labour entailed upon me by the preparation of the present edition has been far greater than that which was required for the last: the literature on the subject, both in Europe and America, having increased so largely that an unusual amount of oftentimes weary reading had to be gone through. If my criticism of the opinions of others should occasionally appear severe, it should be remembered that it is not always possible to separate the wheat from the chaff without a little rough handling.

18 Bryanston Street, Portman Square:
September 1873.

PREFACE

TO

THE SECOND EDITION.

In looking back to the time when the first edition of this work appeared, I cannot help feeling considerable satisfaction at the progress which the subject treated of in this volume has made since then, both scientifically and professionally. Ten years ago medical men held galvanism in very low estimation; reports of cures by electricity were received with an incredulous smile; there was only one hospital—Guy's—where electricity was regularly used; and there it was applied in an antiquated fashion, and its use relegated to nurses or dressers. At the present time not a few hospitals possess the necessary electrical apparatus; able teachers are instructing students in its scientific application; and the first medical society in the kingdom has appointed a committee, composed of some of the most eminent members of the profession, for investigating the therapeutical use of electricity. This is a great change; but quite as great is the change which has come over the scientific aspect of the subject. The physiological action of the different forms of electricity has been much more thoroughly studied than it ever was before;

their place in therapeutics has not only become better defined, but also considerably enlarged, and rests on a firmer basis; and the special indications for the use of the several agents which are comprehended under the name of electricity and galvanism are much better understood. All this must of necessity be a source of gratification to those who have held fast to the remedy in evil times; but just as great and well-founded is their hope that the sphere of practical usefulness of this still mysterious power may in future even be further extended than it is at present. Where scarcely a month passes without an accumulation of new facts showing the beneficial results which may be obtained from a judicious use of electricity in various disorders—and not uncommonly just in those which are not amenable to other remedies, such as progressive muscular atrophy, and epileptiform neuralgia—we may well cherish the hope that, as time advances, and our knowledge of the agent becomes more intimate, further improvements in the mode of using it may be made, and further indications for its therapeutical application may be discovered.

The present edition of this work is considerably enlarged; its therapeutical part has been almost entirely re-written, owing to the accumulation of evidence showing the striking remedial effects of the continuous galvanic current, of which only little was known when the first edition appeared.

Another change in the book has been the introduction of a number of illustrations, which, it is hoped, will greatly contribute to a better comprehension of the text. For the loan of some of them I am obliged to Professor Benedict, of Vienna (figs. 9, 10, 43, 46, 47); M. Gaiffe, of Paris (figs.

49–52, 55); Dr. Morell Mackenzie (fig. 57); Dr. Meyer, of Berlin (figs. 24, 25, 29); Professor Schwanda, of Vienna (figs. 1–8), and M. Tripier, of Paris, author of the 'Manuel d'Electrothérapie,' Paris, Baillière, 1861 (figs. 11, 14–23, 30, 42, 44, 45, 48, 53, 54, 56, 58–60, 62). To all these gentlemen my best thanks are due for their readiness in aiding me to make this work more complete than it could have been otherwise. All the other illustrations are original, and have been taken from the instruments introduced and employed by myself.

In conclusion, I beg to express the hope that the new edition of this work, upon which I have bestowed much time and care, under a heavy pressure of both private and hospital practice, may serve to advance this important department of medical science.

18 Bryanston Street, Portman Square:
December 1869.

PREFACE

TO

THE FIRST EDITION.

THERE ARE FEW REMEDIES employed in the treatment of disease on the value of which the professional mind is less settled than on that of galvanism. Enthusiastic panegyrists contended fifty years ago, and contend still, that it is a therapeutical agent superior to all hitherto discovered, whilst the great majority of the profession entertain serious doubts as to the reality of the remarkable successes which are now and then recorded by medical galvanists.

The differences of opinion about the therapeutical value of electricity are readily to be understood if we bear in mind that the mode in which electricity is applied has an all-important bearing upon the results. It is true that even by a careless employment of galvanism a few accidental successes have been obtained; but in ninety-nine cases out of a hundred, empirical galvanists, being unacquainted with the physiological effects of electricity, have been disappointed, and have brought the remedy into undeserved contempt.

We know that, whatever may be the properties of the nerves, they can be called into action by galvanism. But the

effects are widely different according to the form of electricity that is used; again, the quantity and intensity of electricity are both of great importance; not less so the mode in which it is transmitted to the human body, and the length of time during which its action is kept up. In fact, we are able, by merely varying the modes of applying electricity, to arouse or to kill the vital power of the nerves, and to diminish or to increase their properties. Hence electricity can only be expected to be of service in the treatment of disease, if we are guided in its use by an exact knowledge of the physiological effects which it will invariably produce. I have, therefore, been most anxious to render the physiological part of my work as complete and comprehensive as possible.

That there is at present so little certainty respecting the physiological and therapeutical effects of electricity, is in some measure due to the vast extent of the field that is to be explored, and to the comparatively short time that has elapsed since scientific researches of this kind have been undertaken; also to the intentional falsehoods that have been published, even in the present time, about pretended cures by means of electricity; and especially to the small number of observers who have devoted themselves to the study of these phenomena. We possess a large amount of valuable information and experience concerning the effects of internal remedies upon the system; we know where to procure and how to prepare most drugs; we know how to combine them, and in what cases and in what doses to administer them with advantage. But in respect to electricity we have no such certainty. What form of electricity should be used? in what cases should it be employed? shall we act indiscriminately

upon the different tissues, skin, muscles, and nerves, or shall we limit the action of electricity to each one singly? It is easy to understand that we cannot expect beneficial results from the application of electricity if it is applied by empirical galvanists; if the cases are not well selected; if the apparatus employed does not possess those qualities which are necessary for medical use; if the dose of electricity given is too large or too small, and if, instead of acting upon the diseased part alone, the whole body, or part of the body, is acted upon. If, on the contrary, such mistakes as the above are avoided, electricity will be found a most valuable therapeutical agent, by means of which many morbid states of the system may be relieved, and even wholly cured.

It no doubt sometimes happens that in cases which to all appearance are suited for electric treatment, and in which the agent has even been judiciously employed, it nevertheless produces little or no benefit. In fact, electricity is as little infallible as any other remedy we possess. But nobody will doubt the remedial powers of quinine, if it should happen to leave uncured a few cases of ague; and croton-oil will always be reckoned amongst our most efficacious aperients, although it does not invariably relieve constipation.

There is another important point upon which I feel obliged to dwell: patients are recommended by their physicians to undergo a course of galvanic treatment in many instances only after every other remedy has been tried without success, and when the disease is of such long standing as to afford but little hope of ultimate recovery. What beneficial results might be obtained in certain affections of the nervous system, if the electric treatment were resorted to in an earlier stage

of the complaint, may be conceived from a perusal of the chapter in which the effects of faradisation in a number of cases of hysterical aphonia are detailed. I shall be especially gratified if I succeed in inducing more frequent recourse to the electric treatment in certain forms of neuralgia, which defy all other therapeutical treatment, and which are wonderfully amenable to electricity.

Finally, I must allude to the mistake frequently made of employing galvanism alone without any internal remedies. I am quite satisfied that some affections of the nervous system can be cured by electricity alone; but in the majority of cases a simultaneous internal treatment is of the greatest importance, and should not be neglected if we wish to increase the chances of success.

Most of the cases which are reported in this volume have been observed and treated by me either in one of the Metropolitan Hospitals—King's College, St. Mary's, and Samaritan Free Hospital—or in the private practice of eminent members of the profession, to whose kindness in sending me cases for the electric treatment I beg to tender my sincerest thanks.

March 1859.

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ON

MEDICAL ELECTRICITY.

CHAPTER I.

FORMS OF ELECTRICITY.

In the present state of physical science it is generally admitted that all bodies contain a very subtle and imponderable fluid called Natural Electricity, which is composed of two contrary fluids, termed vitreous or positive, and resinous or negative electricity. We suppose these fluids to consist of an infinite number of smallest particles or molecules, each of which possesses attractive and repulsive powers, the molecules of one attracting those of the other, whilst the molecules of the same fluid repel each other. While bodies are at rest, these fluids exist in such proportion that, although they do not destroy each other, their effect is counterbalanced; since at the same distance the attractive power of one of the fluids is equal to the repulsive power of the other. Natural electricity must therefore be decomposed in order that an action may be perceptible. Decomposition of natural electricity takes place as soon as disturbances of any kind are impressed upon bodies, whereby the equilibrium of the molecules is upset; as, for instance, when bodies are subjected to friction, heat, or chemical action. By such and

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other means an electro-motive force is called into existence, which forcibly separates the two fluids formerly united; natural electricity is decomposed and *active electricity* liberated, the nature and intensity of which present certain differences depending upon the nature of the body from which it is derived and upon the action by which it is developed; but active electricity, whatever may be its source, is identical in its nature; it exerts attractive and repulsive powers, produces heat, light, shocks, magnetism, and may tear apart the elements of chemical compounds.

This theory of the electric fluid is not to be considered final, but only provisional. Indications are not wanting that it may at some future time have to undergo considerable modifications; yet it enables us to classify our facts, and is more in accordance with the present state of our knowledge than any other view.

The principal sources of electricity are friction, chemical action, magnetism, and animal life. These will be briefly considered in the present chapter. We shall first take a short glance at *static electricity*, or electricity produced by friction and inductive action; then proceed to examine *dynamic electricity*, under which head are comprehended galvanism, electro-magnetism, and magneto-electricity; and finally, sketch the present state of our knowledge in *animal electricity*, as produced by the various processes of life.

I.—STATIC ELECTRICITY (*syn.* FRICTIONAL OR FRANKLINIC ELECTRICITY, FRANKLINISM).

Above two thousand years ago the Ionian philosopher, Thales, discovered that pieces of amber (*electron*), when rubbed with a dry woollen cloth, attracted light bodies placed in their neighbourhood; hence he concluded that amber possessed a soul, and was nourished by the attracted bodies. It is now understood that amber, when rubbed,

acquires the property of attracting small pieces of paper and other light bodies, because friction decomposes its natural electricity, and negative or resinous electricity is accumulated upon it. If amber in this condition, *a*, be held near pieces of paper, *p*, the negative electricity with which it is charged at once exercises its attractive and repulsive powers. It decomposes the natural electricity of these bodies, and repels the negative fluid into the ground; the paper, therefore, becomes positively charged, and forthwith obeys the attraction exercised upon it by the negative electricity of the amber. Dry glass rubbed with silk, and sealing-wax rubbed with flannel, exhibit the same attractive power; and the rubber and the rubbed body are always endowed with opposite electricities.

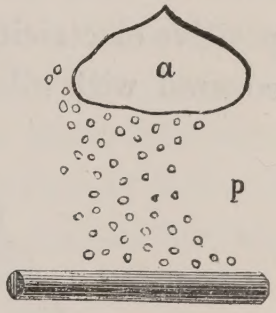


FIG. 1.
The First Experiment.

The *electric machine* was invented in 1671, by Otto von Guericke, then mayor of Magdeburg; and has undergone an infinite number of modifications in course of time. In its present form it consists of a disc of plate-glass, *d*, Fig. 2, p. 4, which is rubbed by leather cushions. These latter are amalgamated with a paste composed of zinc and tin turnings, triturated with mercury and rubbed up with lard. The disc is mounted on an axle of green glass, *a*. At the end of the latter a handle is fixed, *h*, by means of which the disc may be turned round between the leather cushions. When positive electricity is required, a metallic chain, *c*, is fixed to the cushions and connected with the ground, in order to carry off the negative electricity of the cushions; positive electricity then accumulates on the glass disc, and may be drawn off by the prime conductor, *p*, which consists of several hollow brass balls, *b b*, connected by two horizontal glass tubes, *t t*, resting on columns of glass, *g g*, and connected with the

horizontal diameter of the disc. When negative electricity is required, the chain which touches the ground is connected with the disc instead of the cushions, so as to remove the positive electricity which is set free. A portion of the disc is covered with oiled silk, in order to prevent the electricity

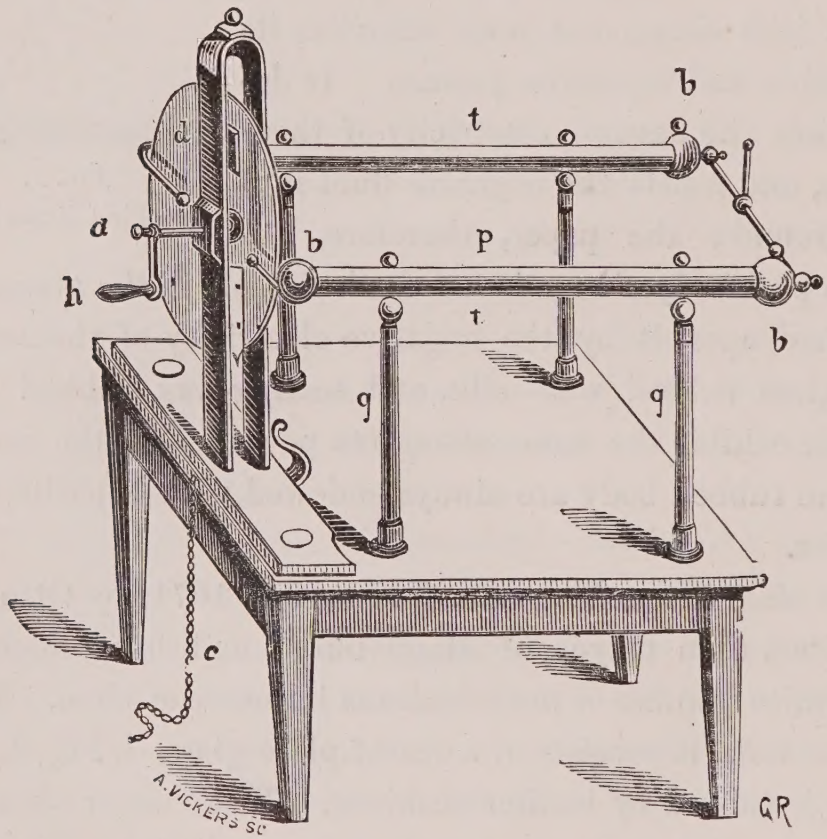


FIG. 2.—The Electric Machine.

from dispersing into the atmosphere. When the machine is in action a peculiar smell is perceived, which is half sulphurous and half phosphoric, and is due to the transformation of the common oxygen of the atmosphere into allotropic oxygen or ozone.

Ozone and Antozone.—In 1839, Professor Schönbein, of Basle, discovered that by the electrolysis of acidulated water an odoriferous gas was produced at the positive pole, which could be preserved for a long time in well-stoppered bottles. He also noticed that the same gas was set free by discharges

of the ordinary electrical machine through air, and when overtaken by a storm on the Jura mountains, recognised the identity of its smell with that accompanying a flash of lightning. The properties of this gas were further investigated by Andrews, Williamson, Baumert, Frémy, Becquerel, Soret, and a number of other physicists, whose researches have established the fact that ozone is an allotropic form of oxygen, and that the two gases are mutually convertible into each other.

Ozone may be chemically prepared by slow oxidation of phosphorus, ethers (*ozoniferous ethers*), chloroform, and most volatile oils, or by mixing three parts of sulphuric acid with two parts of permanganate of potash. The latter mixture will, according to Böttger, continue to give off ozone for several months consecutively; and it is strongly recommended by Dr. Cornelius Fox[1] for the purification of the air of hospitals, public halls, &c.

The peculiar smell which accompanies a lightning flash is due to the transformation of common oxygen into ozone, by means of the electricity discharged through the atmosphere. The gas also appears near the ordinary electrical machine when in action; and large quantities of it may be obtained by electrolysing water which has been acidulated with sulphuric acid, or with a mixture of sulphuric and chromic acids.

The properties of ozone are the same from whatever source it may have been derived, and it differs from common oxygen chiefly by its peculiar odour, which is half sulphurous and half phosphoric, and by an exaltation of its chemical affinities. Ozone is one of the most powerful oxidising agents with which we are acquainted. It purifies water which is charged with organic refuse; destroys the foul odour

[1] Ozone and Antozone, their History and Nature. London, 1873, p. 25.

of sulphuretted hydrogen; oxidises most silver, iron, copper, and mercury; is readily absorbed by dry mercury and iodine; decomposes a solution of iodide of potassium; changes the yellow ferrocyanide into the red ferridcyanide of potassium, and the black sulphide into the white sulphate of lead; corrodes organic matters, and bleaches most vegetable colours. Its bleaching effects are superior to those of chlorine.

A small quantity of ozone is always contained in the atmosphere; but its amount varies considerably, according to the season of the year. Rain, snow, hail, high winds, a low temperature, and the presence of a considerable quantity of atmospheric electricity, are favourable to its development, and ozone is therefore found to be most abundant in winter and spring; while heat, the absence of strong winds, a small quantity of atmospheric electricity, and the presence in the air of a large mass of volatile, vegetable and animal refuse, counteract its formation, or destroy it as soon as developed. In summer and autumn, therefore, ozone appears to be at a low ebb.

Life on our globe could probably not go on if the air were not constantly deprived of its noxious admixtures by this all-pervading principle; but whether a deficiency or an unusually large supply of ozone has any decided influence on epidemic or other diseases, has not yet been ascertained. Most observations which have been made on this point are devoid of value, because the iodised starch-paper test which has been generally employed shows not only the presence of ozone, but also that of the peroxides of hydrogen and nitrogen, nitrous acid, and sulphuric and sulphurous acids in the atmosphere. Extended series of researches with Houzeau's new iodised-litmus test, which shows nothing but ozone, will therefore be necessary for elucidating this question.

Schönbein has also described a body which he called

antozone, and which he believed to be oxygen in a positively polar condition, as distinguished from ozone, which he considered to be oxygen in a negatively polar condition. Recent researches, however, have rendered it certain that antozone is identical with peroxide of hydrogen.

Properties of static electricity.—Of all the different forms of electricity, static electricity exercises the most considerable attractive and repulsive powers, even at a distance; and the energy with which these attractions and repulsions occur, is greater in proportion as the two bodies between which they are exercised are nearer to each other. Mathematically speaking, the repulsive force exerted between two bodies which are *similarly* electrified, varies inversely as the square of the distance; and the attractive force exerted between two bodies *dissimilarly* electrified, follows the same law.

Gray discovered, in 1729, that all metals and most liquids propagate any electricity which is communicated to them, thoughout their entire substance; while other bodies, such as glass, silk, resin, &c., arrest its passage. The former kind are therefore called *conductors*, and the latter *insulators* of electricity. Gray succeeded in carrying electricity to a distance of 250 yards from the spot where it was generated, thus making the first step towards the production of the electric telegraph. Subsequently Dr. Watson, Bishop of Llandaff, succeeded in sending the discharge from a Leyden jar through 10,600 feet of wire, which he supported on insulators of wood. These experiments were made on Shooter's Hill, in 1747. The first electric telegraph was established in 1833, by Gauss and Weber, Professors at the University of Göttingen, between the Physical Laboratory and the Astronomical and Magnetic Observatories of that city; and this embraced a distance of about 12,000 feet.

When bodies charged with contrary electricities are

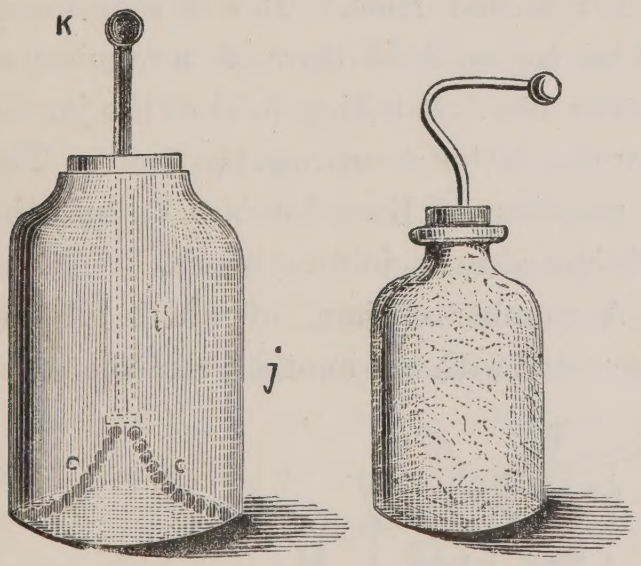
approached to one another, the two fluids become neutralised; and during the act of neutralisation the *electric spark* is produced, the discharge of which is accompanied with a peculiar snapping or crackling noise. When the electric machine is made to act in a dark room, streams of fire are seen to come from beneath the oiled-silk covering, and to disperse over the plate. If the hand be held at a short distance from the conductor, a curious streaming or wave-like sensation is experienced; and if it be brought close to it, sparks pass from one to the other, causing a sharp pungent sensation in the skin, and a white rash, which is sometimes surrounded by a little inflammatory blush.

In the moment of neutralisation, electricity is no longer at rest, but in motion or the dynamic state. The state of motion is instantaneous, if the two bodies, which were charged with contrary fluids, acquire no more electricity after that which they had before has once become neutralised; and this instantaneous dynamic state is termed the *electric discharge.*

A discharge is instantaneous; but if the two electricities be constantly renewed, one of the bodies deriving from any source a continuous supply of positive, and the other one a like supply of negative electricity, a continuous neutralisation will go on either through the air with sparks, or through a conductor. This continuous dynamic state is termed the *electric current.* The essential difference between a discharge and a current is, that a simple discharge, although it produces a number of other effects, has no action upon a magnetised needle; whilst an electric current is capable of deviating it from its previous position. By a rapid succession of discharges, however, the needle may be deflected just as it is by the voltaic or electro-magnetic current.

The Leyden Jar.—The Leyden jar was invented in 1745, by Kleist, then prebendary of Cammin, in Pomerania, and

sometime afterwards independently of him, by Muschenbroek, of Leyden. It consists of a rather wide-mouthed glass jar, *j*, Fig. 3, which has an inner and outer coating of tinfoil. The inner coating is connected with a brass rod, *r*, which passes through the stopper of the jar, and terminates above in a brass knob, *k*, two or three inches above the stopper; it ends below in a brass chain, *c*, which rests on the bottom of the jar. The jar is charged by connecting the outer coating with the ground, which is done by holding it in the hand, while the knob which communicates with the inner coating is presented to the prime conductor of the electrical machine.



FIGS. 3 and 4.—The Leyden Jar.

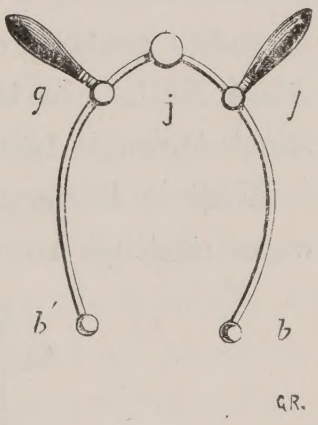


FIG. 5.—Metallic Discharger.

Thus the positive electricity of the machine passes down the brass rod to the inner coating of the jar, on which it accumulates, while negative electricity appears on the outer coating. The jar is discharged by establishing a connection between its outer and inner surfaces.

The metallic discharger (fig. 5,) which is generally used consists of two brass rods, *bj* and *b'j*, terminating in balls, *b* and *b'*, and connected by a joint, *j*. They are furnished with insulating handles of glass, *g* and *g'*, by which they are held. If one of these balls be made to touch the brass knob

of the jar, and the other its outer coating, a brilliant spark is perceived, and the usual snapping noise is heard. The jar may also be discharged directly through the human body by holding it in one hand by the outer coating, and then touching the brass knob by the other hand. This produces a violent, sudden, and painful sensation, the *electric shock*, the force of which is proportional to the area of the metallic coating and to the intensity of the charge.

Kleist was the first who felt this shock; Muschenbroek, who also received it unexpectedly, and who had less nerve, wrote to Réaumur that 'not for the kingdom of France would he expose himself to it a second time.' It was soon found that the shock could be transmitted through a number of persons forming a chain; the first taking hold of the jar by its outer coating, and the latter touching the knob. The Abbé Nollet, in the presence of King Louis XV., sent the shock through 180 life-guardsmen, joining hands.

Electric Battery.—A number of jars, of which all the outer coatings are connected with one another, and the inner

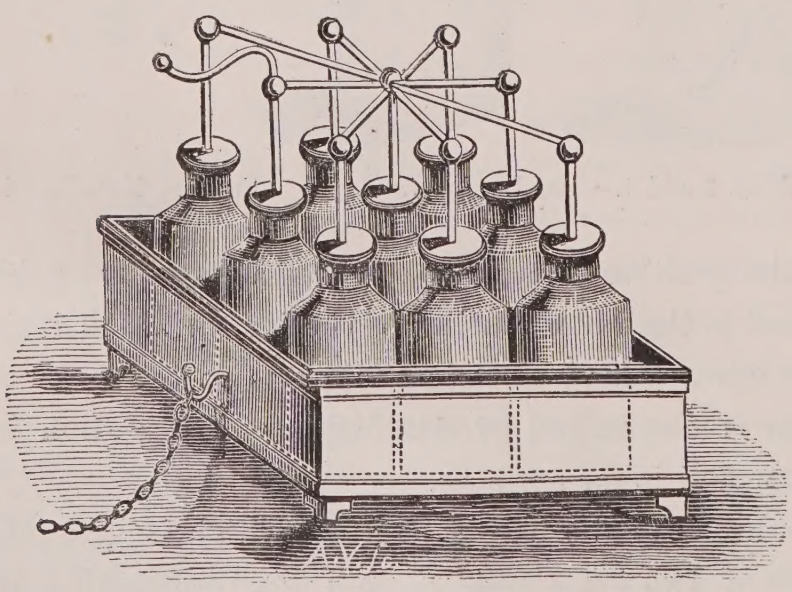


Fig. 6.—The Electric Battery.

coatings likewise, forms an *electrical battery*, the power of which is proportionate to the size and the number of the

jars. A jar or a battery, however, cannot be charged infinitely, as, when a certain quantity of electricity has accumulated, the tension becomes so high that the electricity either shatters the jar or is discharged spontaneously. A shock from a powerful battery may destroy life, the same as lightning.

Quantity and Intensity.—The quantity of frictional electricity depends upon the extent of the electric source from which it is derived, and the extent of surface upon which it is accumulated. Intensity, on the other hand, denotes the tendency of the electricity to escape from any place in which it is confined, and to overcome any impediments to its passage. This latter varies according to the manner in which the electricity is distributed. Mr. Watts [1] has appropriately likened the manner in which the term 'intensity' is used with regard to electricity, to the way in which the term temperature is applied with respect to heat. Thus, a pint of water at 100° C. produces many effects which a gallon of water at 50° cannot produce; for instance, it will cause alcohol to boil, and fat to melt, although the quantity of heat in the pint, as measured by the quantity of ice which it will melt, is actually less than that contained in the gallon. In the same manner, a small quantity of electricity confined in a small space exerts a greater repulsive force than a larger quantity which is distributed over a comparatively larger surface.

Professor Tyndall [2] has given another apt illustration of these conditions. He says that a cubic inch of air, if compressed with sufficient power, may rupture a rigid envelope; while a cubic yard of air, if not so compressed, may exert only a feeble pressure upon the surfaces which bound it. Now frictional electricity is in a condition analogous to the

[1] A Dictionary of Chemistry, vol. ii. p. 383. London, 1864.
[2] Notes on Electrical Phenomena, p. 15. London, 1871.

compressed air; its density or tension is very considerable. Voltaic electricity, on the other hand, resembles the uncompressed air; its quantity exceeds enormously that of the machine; but it falls much below it in intensity.

Density.—If the quantity of electricity imparted to the same conductor be increased, the *density* of electricity is said to be increased. This density is the same at all points of the surface of a sphere; on a plate the density is greatest at the edges; and on a pointed conductor it is greatest at the point.

The Electroscope.—The electroscope is an instrument by means of which the presence and kind of electricity, whether positive or negative, are indicated. The most simple kind

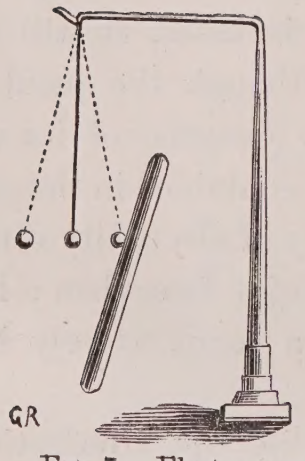


FIG. 7.—Electroscope.

FIG. 8.—Electrometer.

of electroscope is a pith ball suspended by a silk thread, Fig. 7. This is first charged by touching it with a glass rod on which positive electricity is accumulated, and then approached to the object which is to be examined. If no effect on the pith ball be produced, the object is not electrified; if the ball be repelled by it, the electricity is positive, and if it

be attracted, the object is negatively electrified. The instrument generally used, however, is the gold-leaf *electrometer*, Fig. 8, which was invented by Bennet, and perfected by Singer and Buff. The essential parts of this instrument are two strips of gold-leaf, *g*, *l*, suspended in a glass jar, *j*, which is open at both ends. A brass rod, *r*, passes through the neck of the jar, which is closed by a cap, *c*. The strips of gold-leaf are attracted to the lower end of the rod, while a brass cap, *b*, rests on the upper end of the same. An electric charge communicated to the cap *b* is at once conducted to the gold leaves, and causes them to diverge.

Velocity of Electricity.—The velocity with which electricity is propagated is greater than that of any other agent with which we are acquainted, light not excepted; for while light moves at the rate of 192,000 miles in a second, electricity travels, according to Prof. Wheatstone, over a distance of 288,000 miles in a second. This velocity, which is sufficient to make the circuit of the earth ten times in a second, is so great, that any artificial motion which can be produced, appears to be rest itself when compared with it. The light of the electric discharge lasts, according to the same observer, hardly the millionth part of a second. If a wheel, which is made to revolve so rapidly that its spokes become invisible, be illuminated by a flash of electric light, all the spokes are for an instant seen perfectly distinct, as if it were in a state of rest. Insects on the wing appear fixed in the air; a moving cannon-ball illuminated by a lightning flash, seems to stand still; and an apparently continuous stream of water is seen as a succession of drops; the cause of these phenomena being, that, however rapid the motion of bodies may be, the electric light has come and passed away before the motion has gone over a perceptible portion of space.

It should be understood, however, that electricity travels

at this high speed only when unimpeded by disturbing causes, and that this rate is, in ordinary transmission, considerably diminished by the influence of neighbouring bodies, and the varying conductivity, and the more or less imperfect insulation of the wires used for sending it on.

Thus Faraday found that, in the subterranean wire of the London and Manchester line, the current took two seconds to run over a distance of 1,500 miles; while, with the same length of wire in the air, the space of time was almost imperceptible. The velocity of the London and Brussels submarine telegraph is 2,700 miles in the second, this low rate being, in great part, due to the strong conductivity of the sea water, in which a portion of the wire is immersed. In the French telegraph wire, on the other hand, which is more perfectly insulated, the rate of transmisssion is 112, 680 miles in the second.

The following table shows the rate at which electricity, light, sound, nervous force, and other agents, are transmitted:—

	Mètres in the Second.
Electricity	464,000,000
Light	300,000,000
Shooting-star	64,380
Earth in orbit round the sun	30,800
Sound in iron	3,485
Sound in water	1,432
Cannon-ball	552
Earth's surface at Equator	465
Sound in air	332
Eagle's flight	35
Nervous force	26–30
Railway-engine	27
Greyhound	25
Racehorse	25
Stone thrown by hand	21·9
Arterial wave	9·25
Blood in dog's carotid	0·2 to 0·3
Blood in dog's capillaries	0·0006 to 0·0009
Particles moved by cilia	0·00007

Fig. 1.

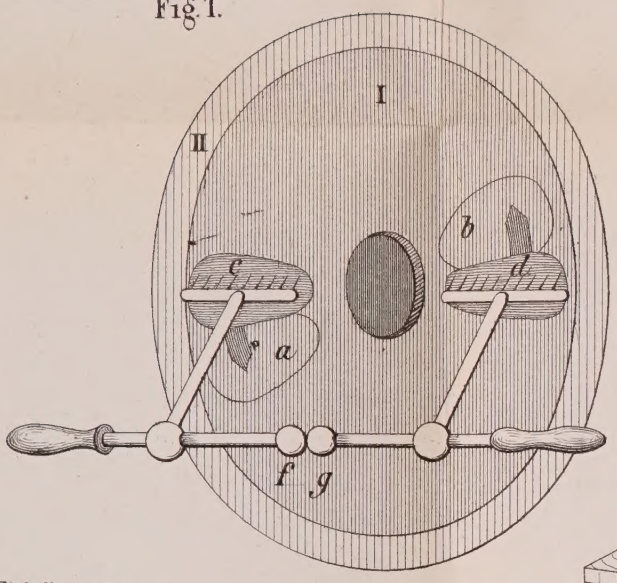
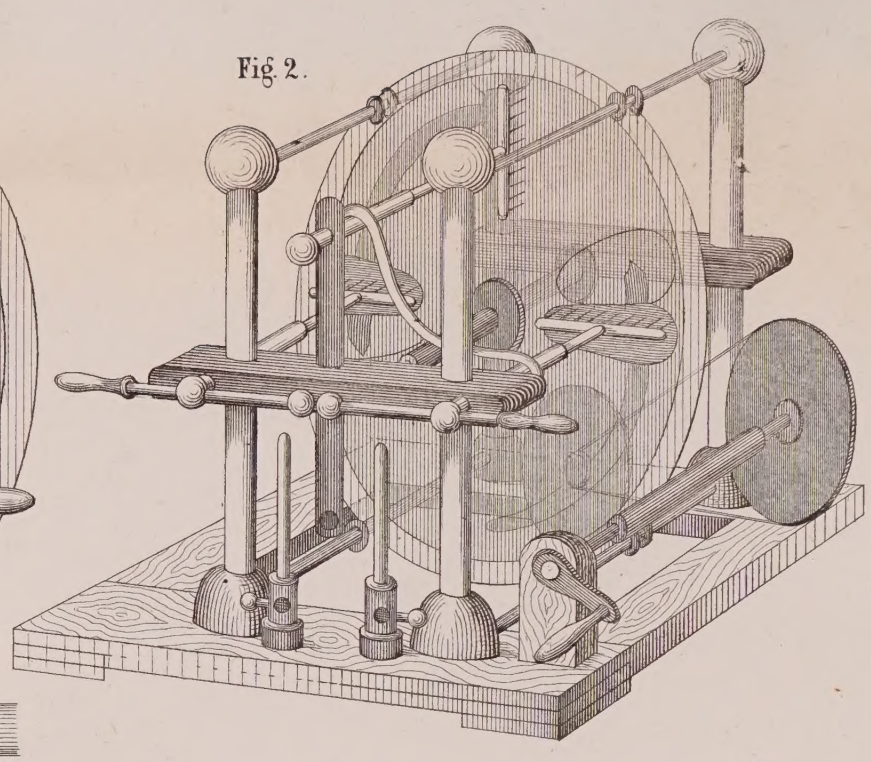


Fig. 2.



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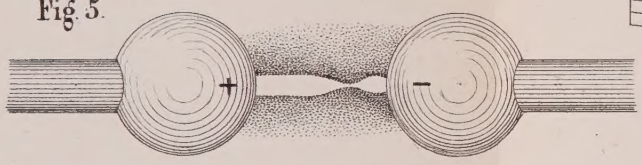

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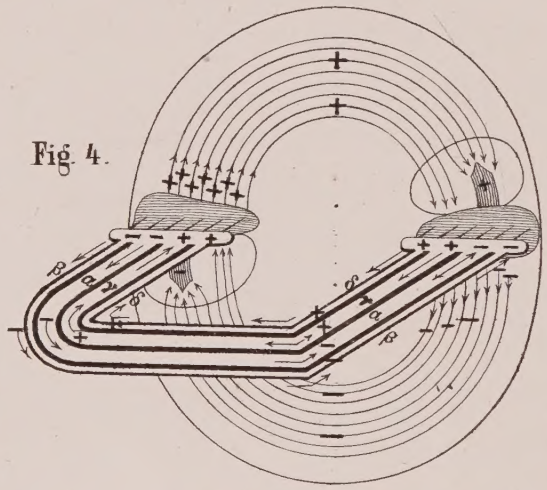
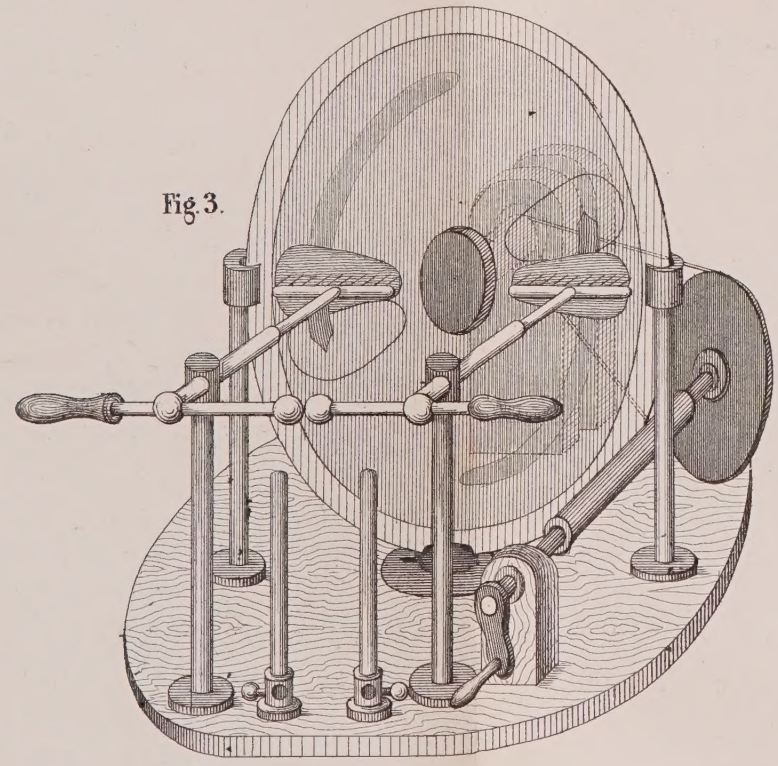


Fig. 3.



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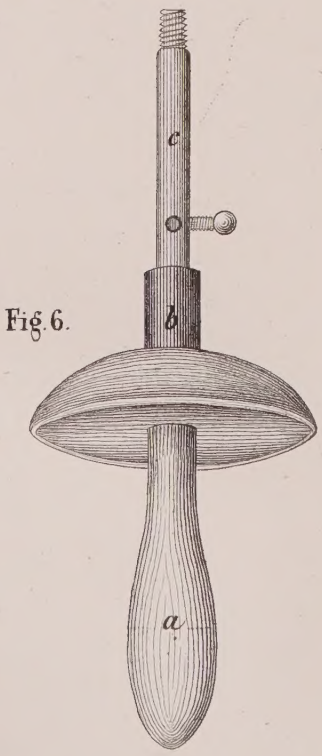


Fig. 7.

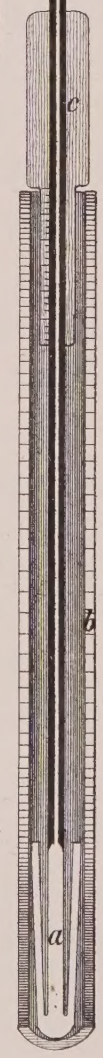
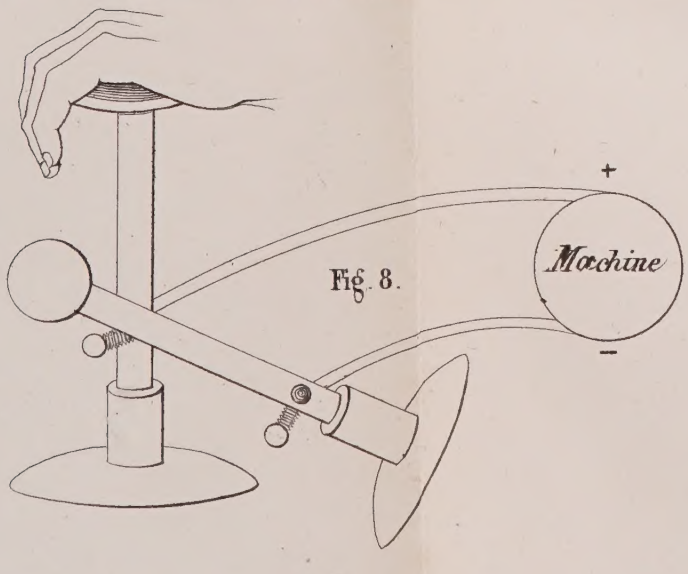


Fig. 8.



Schwanda del.

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The fact that electricity moves at a rate of 288,000 miles in a second, while nervous force travels in the same space of time only over a distance of about thirty yards, is sufficient to prove that *electricity and nervous force are not identical*, as some physiologists are inclined to believe.

Chemical Effects.—That frictional electricity has certain chemical effects was discovered by Priestley, who succeeded in forming an acid out of oxygen and nitrogen by passing a succession of shocks through air. This subject was most elaborately investigated by Faraday, who found that the chemical action of frictional electricity is very feeble, since the quantity of matter decomposed is not proportionate to the tension, but to the quantity of electricity employed, and the quantity of frictional electricity is small. The voltaic pile, on the other hand, yields a very large quantity of electricity, and therefore produces chemical decomposition with the greatest facility. Faraday has calculated that the great Leyden battery of the Royal Institution would require to be charged by 800,000 turns of a powerful plate machine of fifty inches in diameter, to supply electricity sufficient to decompose a grain of water. If this charge of the battery were concentrated in a single spark, it would resemble a great flash of lightning; yet its quantity would only be equivalent to that which is produced in about five seconds by a single pair of Grove's battery. Faraday has also estimated that the quantity of electricity in action, during a severe thunderstorm, would correspond to the quantity of electricity set free by the chemical action of one grain of water on four grains of zinc.

Inductive Action; Electrophorus.—Static electricity does not only produce certain effects when two bodies are in contact with each other, but also at a distance; and these latter effects are said to depend on inductive action. An

electrified body which is approached to an unelectrified insulated conductor, decomposes the neutral electricity of the latter, attracting one fluid and repelling the other; but, as soon as the electrified body is withdrawn, the fluids reunite and become neutralised.

The most important instrument for showing inductive action is the Electrophorus, Fig. 9, which was invented by Wilke, and improved by Volta. It consists of a cake of resinous matter, *c*, or a plate of ebonite, contained in a metallic plate, *p*, with a rim round its edge, and is provided with a metallic cover, *m m*, which is furnished with an insulating handle of glass, *h*. The surface of the cake is negatively electrified by striking it briskly several times with a fox-tail

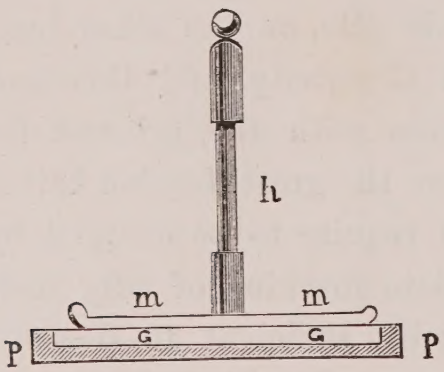

FIG. 9.—Electrophorus.

or a piece of fur, after which the cover is laid on. The natural electricity of the cover is now decomposed by the negative electricity of the cake; positive electricity is attracted, but the negative fluid repelled, and therefore positive electricity accumulates by induction in the lower, and the negative fluid in the upper portion of the cover. If the finger be now approached to it, a spark is seen; and if the finger touch the cover, all the negative electricity is repelled, and the cover is charged with the positive fluid, which is confined by the negative electricity of the cake, as long as the cover remains on the cake. But when the cover is removed,

positive electricity is set free, and a spark may then be drawn from the cover. From this it is concluded that the electricity of the movable plate is not derived as a charge from the resinous cake, but is the result of inductive action. This process takes place not through the metal, but through the air, and is an action of the contiguous particles of the insulating body thrown into a state of polarity and tension, whereby they are rendered capable of communicating their forces in every direction.

Holtz's Electrophorus Machine.—The principle of inductive action has recently been utilised by M. Holtz, of Berlin, and M. Töpler, of Riga, both of whom have constructed inductive machines of extraordinary power (1865).[1]

(Vide Lithographic Plate, figs. 10 and 17.)

The electricity furnished by these machines is in all respects identical with frictional electricity, except that it is not developed by friction, but by inductive action, as in the electrophorus. They are called electrophorus machines, or rotation-multipliers—a multiplier being a name given to every apparatus the object of which is to multiply by successive transmissions any feeble electric charge which has once been communicated; such transmissions taking place in these machines by means of a rotatory movement.

The essential parts of Holtz's machine are two glass discs—one of which may be turned round its axis, while the other is fixed—and a variable number of conductors. There are three sizes of the disc—namely, 24, 42, and 60 centimètres. The movable disc, I., fig. 10, has a diameter of about thirty-two centimètres, and is two millimètres thick; it consists of plate glass, and is fixed centrically and perpendicularly on an axle of vulcanite, by means of which it may be put into rotation. The fixed disc, II., has a diameter of thirty-six

[1] Holtz, in Poggendorff's 'Annalen,' April and September 1865; Clemens, in 'Deutsche Klinik,' 1867, No. 48; and chiefly Schwanda, in 'Medicinische Jahrbücher,' 1868, Heft iii.; and Poggendorff's 'Annalen,' vol. cxxxiii. p. 126.

centimètres; it consists likewise of plate glass, and has an opening in the centre, so that the axle, which has just been mentioned, may be put through it without friction. It is fixed at a small distance from the movable disc, and parallel with it. This fixed disc is interrupted towards the two extremities of one of its diameters by two oval incisions, *a*, *b*, which are $8\frac{1}{2}$ centimètres long and six centimètres wide. On that surface which is turned away from the movable disc, it is furnished with an equally long paper-coating, *c*, *d*, along each longitudinal side of the incisions; and from these paper-coatings a pointed piece of card-board proceeds into the middle of the corresponding incision. Both glass discs and paper-coatings are covered with sealing-wax.

The metallic conductors are shaped somewhat like a comb with ten finely-pointed teeth, and are fixed as near as possible to the rotating disc, but without touching it, and parallel to the longitudinal direction of the paper-coatings. Each of these combs has a metallic stem, which is placed parallel with the axle, and perpendicularly to the rotating disc. The metallic continuation of the conductors are the electrodes of the machine, fig. 10, *f* and *g*.

In order to put this machine into action, the two electrodes are connected with one another, and the movable disc is turned round by the vulcanite handle, while at the same time a plate of vulcanite which has been rendered electric by friction is approached to one of the paper-coatings, and removed from it as soon as a crepitating noise is heard. The rotation must be so performed that the several portions of the movable disc first pass the incisions, and afterwards the paper-coatings of the fixed disc. As soon as this is done, both coatings are charged with opposite electricities, the density of which grows rapidly, and reaches its maximum within a few seconds.

When the machine is in action, a loud crepitating noise is heard at the pole where the charge takes place, which in-

creases with the force of the charge, and continues in the same manner as long as the conducting arch is closed; but if the latter be opened, the force of the sound is diminished. The smell of ozone is perceived at both poles of the machine, but more strongly at the negative pole. This smell spreads rapidly through the air, so that, after the machine has only acted for a few minutes, a large room is completely filled with it. Luminous appearances take place at both poles as soon as the machine is put into action, and increase rapidly in force and extent. By daylight they become only perceptible when a dark object is held behind the glass discs, while in a dark room they at once appear in all their brilliancy. It is then noticed that a reddish-blue light streams from the points of the comb opposite to that paper-coating where the charge takes place, and that waves of light pass from there in a quarter-circle towards the movable disc, opposite to the direction in which rotation is performed, from whence they proceed farther and farther until they reach a maximum of length, which is about 8 or 10 centimètres. At the same moment when light appears at the points of the negative pole, a similar light is perceived at the points of the positive one; but this has a more reddish hue, and is not quite so dazzling. If the distance between the electrodes is very small, a brilliant white light with a greenish hue is seen, whatever may be the size or the shape of the electrodes; but if the distance be increased, streams of a violet light pass from the positive to the negative electrode. The violet light appears to be due to incandescent nitrogen, while the white light arises from incandescent oxygen.

II.—DYNAMIC ELECTRICITY.

(A.) *Galvanism, voltaic electricity, or the continuous current.*—If two heterogeneous metals, such as copper and zinc, be connected by means of a conductor moistened with

water, various phenomena are produced, the cause of which is ascribed to an imponderable fluid developed by the connection of the metals, and called galvanism, or galvanic electricity, after Luigi Galvani, of Bologna, who discovered this form of electricity in 1786.

Galvani observed that, if the hind-legs of a frog which were lying on an iron grating, were touched by a copper wire, they become convulsed (fig. 18). He did not, however, recognise that the contact of two dissimilar wires was necessary for producing this effect. This was discovered by Volta, who concluded that the electricity produced under

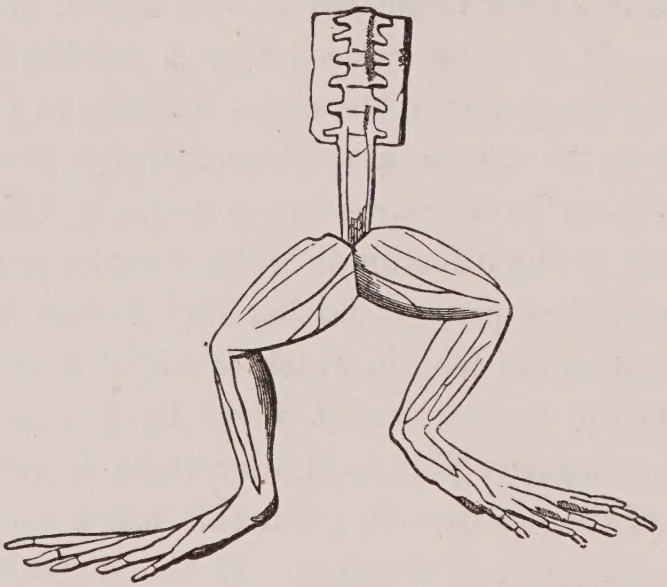

FIG. 18.

these circumstances was owing to the contact of the different metals. Up to a recent time, galvanism was therefore termed *electricity by contact*, for Volta had taken great pains to prove that the liberation of this form of electricity was entirely due to the contact of the two metals, and that the liquid between them merely played the part of a conductor. Volta's theory, however, has been upset by the experimental researches of Davy, Becquerel, de la Rive, and Faraday, who have established the fact that the real source of galvanic electricity is not contact, but the chemical action of two heterogeneous conducting bodies; that contact

is only a condition most frequently necessary, but not always indispensable for the manifestation of the electric signs. that galvanic electricity may be produced not only by the action of a liquid upon a solid—which, it is true, produces the most remarkable electric phenomena—but likewise by the action of two liquids upon each other, or even by gases acting upon solids and liquids. In Galvani's experiment, the electricity is developed not by the contact of the iron, copper, and muscle, but by the chemical action of the moisture of the frog's legs on the pair of metals, and more especially on the iron wire.

Every chemical action is accompanied by a disturbance in the equilibrium of the molecules of a body, and consequently by a liberation of electricity. Where there is no chemical action, no electricity will be set free. We may thus, for instance, establish the most perfect contact between a pair of iron and copper, and immerse it into a well-conducting liquid, such as a solution of potash; but nevertheless the pair remains inactive, because the liquid is incapable of exercising a chemical action upon either of these metals. Again, plates of gold and platinum may be immersed in pure nitric acid, and the most delicate tests at our disposal will give no evidence of galvanic action. But if a drop of hydrochloric acid be now added, a powerful current is set up, flowing from the gold through the acid to the platinum. This is owing to the circumstance that nitric acid has no chemical effect on gold or platinum, while nitro-hydrochloric acid attacks both, and more especially the gold.

The metal which is most attacked in a galvanic circuit is called *positive*, and that which is less or not at all attacked, *negative*. The positive metal determines the direction of the current.

All metals are good electro-motors—that is to say, they give rise to an abundant development of free electricity, if

properly arranged. Considerable differences exist, however, in this respect, according to the nature of the metal. Thus for instance, zinc, if combined with platinum, becomes more strongly charged with positive electricity than if in contact with copper; on the other hand, copper, which in contact with zinc becomes negatively electrified, acquires positive electricity if combined with platinum. The following table shows the principal electro-motors arranged according to their polarity, the preceding one being positively electrical to all the following ones :—

+	Iron.	Platinum.
Zinc.	Copper.	Carbon.
Lead.	Silver.	—
Tin.	Gold.	

The greater the distance between these several substances the more considerable is the galvanic intensity—a combination of zinc and carbon being the most active pair of all.

The force which urges the galvanic current forwards is considerably less than that which propels a current of frictional electricity. In a galvanic pair the two contrary electricities have no difficulty in re-uniting through the intermediate liquid; but such a current could not jump over a perceptible portion of space. We may, however, give more tension to a galvanic current by uniting a number of pairs in regular order, so that the negative metal of the first is connected with the positive of the second, and so on. By building up a number of such pairs, the galvanic current becomes more similar to frictional electricity; yet it has been shown that an ordinary electric machine would urge its current across an interval with infinitely greater force than a thousand galvanic pairs would do. On the other hand, the magnetic and chemical force of galvanism is incomparably greater than that of frictional electricity. The latter is therefore said to possess a high degree of *tension*, and the former an enormous *quantity*.

The compound galvanic circuit was invented by Volta in 1800, and is generally called the *voltaic pile.*

The original voltaic pile (fig. 19) consists essentially of three substances: viz., of two metals which become charged with electricity, and an indifferent conducting body. It is built up in the following way:—A copper disc is placed upon a glass plate, a zinc disc upon the copper disc, and a circular piece of cloth, flannel, or pasteboard, soaked in water or salt-water, upon the zinc disc. A second similar pair is piled on the first, a third on the second, and so on up to twenty or more. As soon as the pile is in action, the water moistening the flannel is decomposed, and hydrogen accumulates upon the copper, while oxygen goes to the zinc.

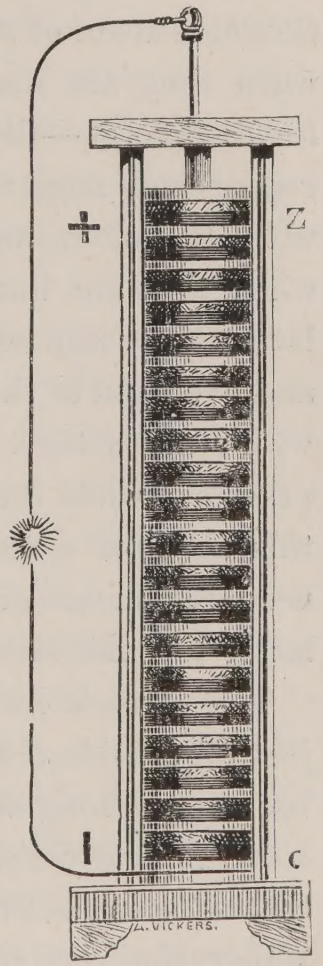

FIG. 19.—Voltaic Pile.

If a little sulphuric acid be added to the water, the galvanic action is intensified, partly because the acidulated liquid conducts better than ordinary water, and partly because the oxide of zinc is removed as soon as formed, as it combines with sulphuric acid to form sulphate of zinc, which is soluble in water.

The top or zinc end of the pile is called the *positive pole*, the bottom or copper end of the pile is termed the *negative pole.* If the two poles of the pile be connected by conducting wires, these latter become charged with the electricity of the poles, and we therefore have a positively and negatively charged conductor.

That the force produced by the voltaic pile is really electricity, is shown by a large number of facts. Thus the poles

of the pile are seen to repel similarly electrified bodies, and to attract the dissimilarly electrified. A Leyden jar may be charged by connecting one of its coatings with the positive and the other with the negative pole of the pile. When the two conducting wires are approached to each other, a continuous stream of small sparks is seen to pass between them; when they are made to act on the electroscope, the gold leaves diverge—the zinc end showing positive, and the copper end negative, electricity; when they are touched with the fingers, an electric shock is felt through the arms; when they are immersed in a vessel containing water, the latter is decomposed, oxygen being attracted to the positive, and hydrogen to the negative pole; when they are connected with a magnetised needle, this is deflected from its previous position; when they are made to touch a piece of soft iron, this acquires magnetic properties; and when they are connected by means of a thin wire of low conducting power, the latter becomes incandescent.

The electric current furnished by the voltaic pile is subject to considerable variations; and although it may have been very strong at first, soon diminishes in strength, and at last completely disappears. This is owing to the circumstance that as soon as the pile is put into action the water with which the conductor is moistened becomes decomposed, whereby the surface of the metals is altered, and their heterogeneity more or less destroyed. When in this condition, the metals are said to have acquired *polarisation*. If a liquid were used that is incapable of decomposition, no galvanic effect would be caused; so that polarisation is inevitable. A fresh current is now produced—the *polarisation current*—which flows in a direction contrary to that of the battery, and has, therefore, the tendency to neutralise the original current. The longer the action of the battery continues, the more considerable is the decomposition which

takes place ; and the polarisation current, therefore, becomes at last so strong that it completely neutralises the original current. The action of the battery is then arrested.

Constant Batteries.—The effects of polarisation may be to a great extent avoided by using *two conducting liquids* which are separated by a permeable membrane or a porous vase, instead of one liquid only. In such batteries the water is decomposed, just as in the ordinary voltaic pile ; but the hydrogen is bound again as soon as set free, whereby the polarity of the plates is preserved for a longer time than in the original arrangement. Batteries of this kind are therefore called constant batteries. Each such battery consists of five substances : viz. 1st, a metal which is attacked, and at the expense of which the electricity is produced ; this is generally zinc, and forms the *negative pole* of the battery ; 2nd, a substance which attacks the zinc, and which is generally an acid ; 3rd, a porous diaphragm ; 4th, a depolarising body, generally a solution of sulphate of copper ; and 5th, a collector which is not attacked, such as copper, platinum, or carbon, and which forms the *positive pole* of the battery. Any number of such pairs may be combined to form a pile.

Becquerel's Battery.—The very great merit of having constructed the first constant battery belongs to M. Becquerel, who proposed to immerse copper as well as zinc in a special liquid, both being separated from each other by a porous diaphragm which allows communication between the two liquids. Becquerel's pair (fig. 20, p. 26) is contained in a cylindrical vessel, *v*, of glass or porcelain ; a cylinder of zinc, *z*, is placed in this vessel, and acidulated water filled into the space between the vessel and the zinc. In the interior of the cylinder of zinc is placed a bladder, *b*, containing a hollow copper cylinder, *c*, and a concentrated solution of cupric sulphate. At the bottom of the copper cylinder is some sand, *s*, to keep it steady. When the poles of this pair, *pn*,

are connected, both the water and the solution of cupric sulphate are decomposed. One part of the liberated oxygen combines with the zinc to form oxide of zinc, which combines again with sulphuric acid to form sulphate of zinc; another part of the oxygen combines with hydrogen to form water; and finally, a thin film of copper is deposited on the surface of the copper cylinder, which is, therefore, not altered. It is easy to understand that Becquerel's battery must furnish a much more constant current than the ordinary

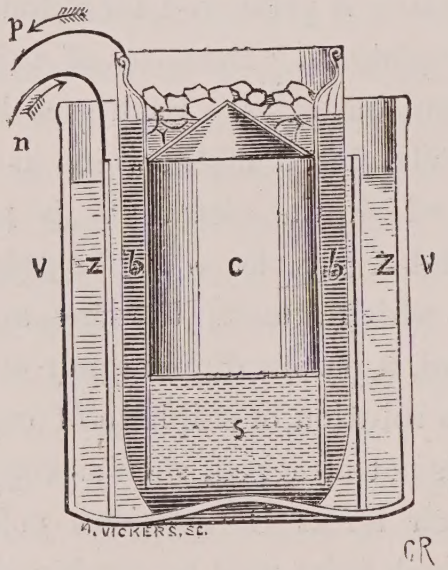

FIG. 20.—Becquerel's Battery.

voltaic pile. In Becquerel's battery zinc is the negative, and copper the positive pole.

Electro-therapeutists can never be sufficiently grateful to Becquerel for having conceived and carried out the idea of the constant battery. Becquerel's arrangement, with certain modifications introduced subsequently by other physicists, is still the only really constant battery in existence, and the one that is more useful than any other for the medical application of electricity.

Daniell's battery (fig. 21, p. 27) is a modification of Becquerel's, and consists of a cylinder of zinc, *a*, immersed in a mixture of one part of sulphuric acid and eight parts of

water ; and a copper cylinder, *b*, placed in a concentrated solution of cupric sulphate. The chemical decomposition which takes place in this pair is exactly the same as in Becquerel's ; but it has the advantage of having a diaphragm of porous earthenware, which is not so easily spoilt as one of bladder, and which can be conveniently employed in the form of a vessel ; besides which the zinc of the pair is amalgamated, which prevents its being attacked at a time when the poles of the battery are not united by a conductor, without in any way diminishing the effect of the zinc in the production of

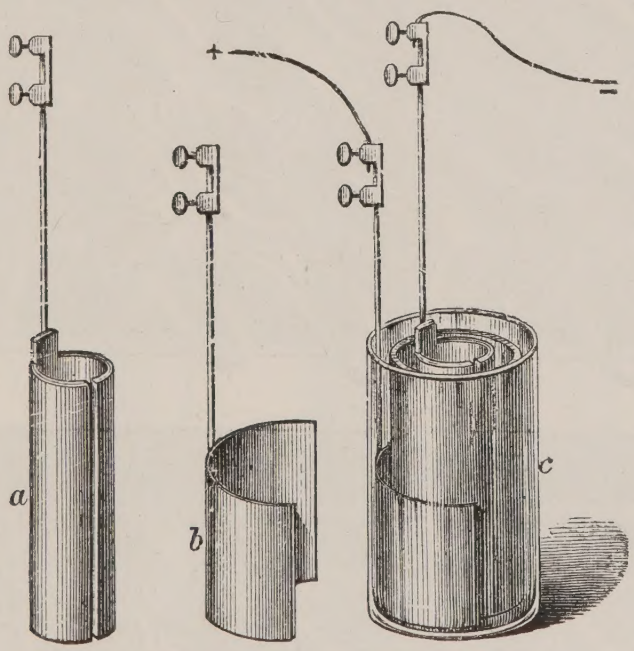

FIG. 21.—Daniell's Battery.

electricity. The ordinary zinc of commerce is impure from the admixture of other metals, and its surface is therefore never completely homogeneous. This gives rise to local galvanic currents when it is immersed in acidulated water, whereby the metal is rapidly destroyed. By amalgamation the surface of the zinc is rendered pure and homogeneous, and it becomes more strongly positive than it was before. The best way to amalgamate zinc is to immerse it in diluted sulphuric acid, after which a solution of mercury in nitro-hydrochloric acid

is painted over it with a camel-hair brush. The solution of mercury is made by gently heating four parts of mercury in five parts of nitric and fifteen parts of hydrochloric acid, after which twenty parts of hydrochloric acid are added to the mixture.

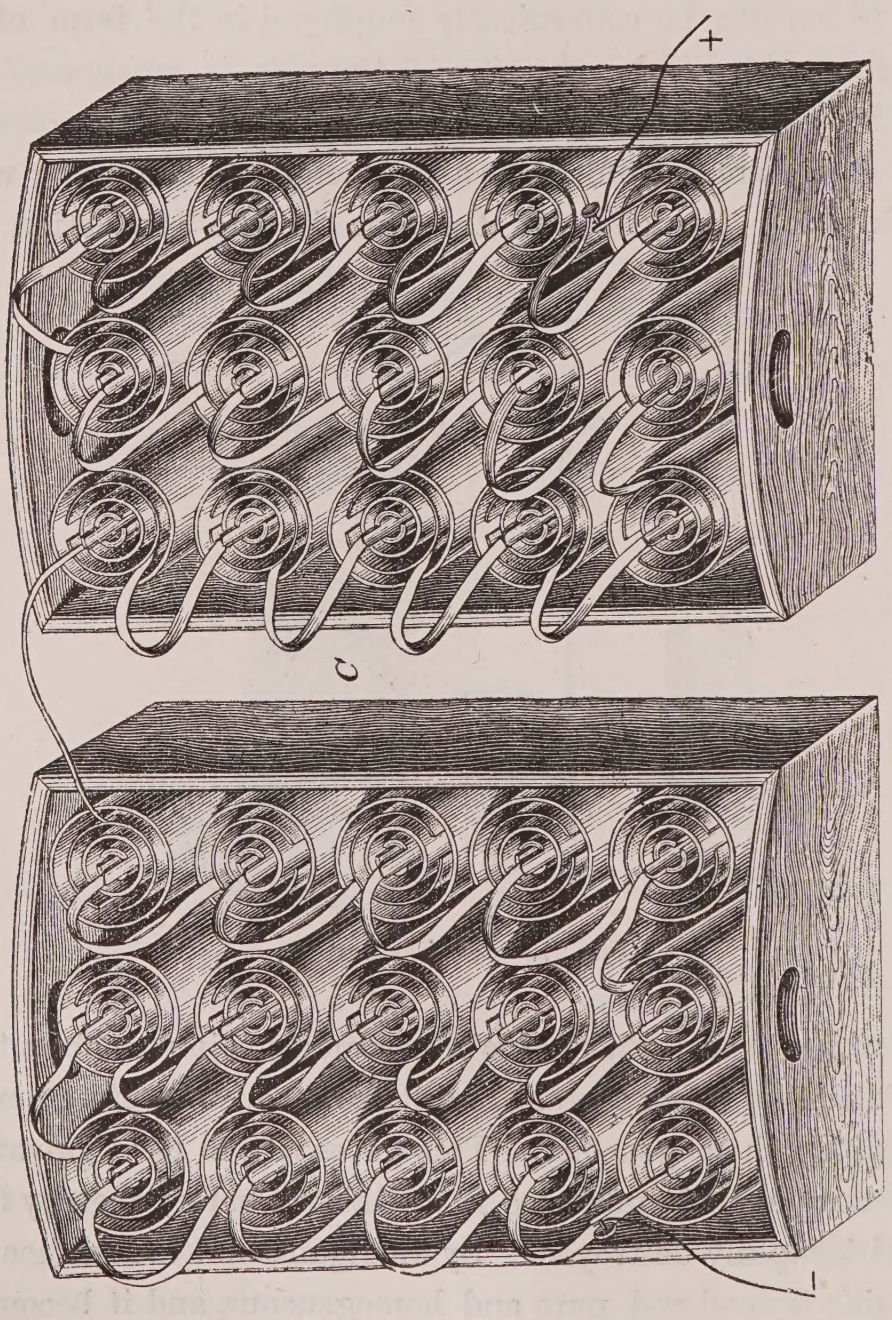

Fig. 22.—30 pairs of Daniell's Battery.

Daniell's battery is distinguished for its constancy, and the ease with which it is kept in order. In course of time, however, the porous diaphragm becomes obstructed with

crystals of sulphate of zinc, and therefore offers more resistance to the passage of the current; besides which, by the precipitation of copper in a finely divided state on the zinc, local currents are formed, by which the zinc is further attacked, and the constancy of the battery impaired. It has therefore to be cleaned, and requires a fresh supply of cupric sulphate from time to time.

Grove's Battery.—In Grove's battery, which is one of the most powerful that have been constructed, the copper is re-

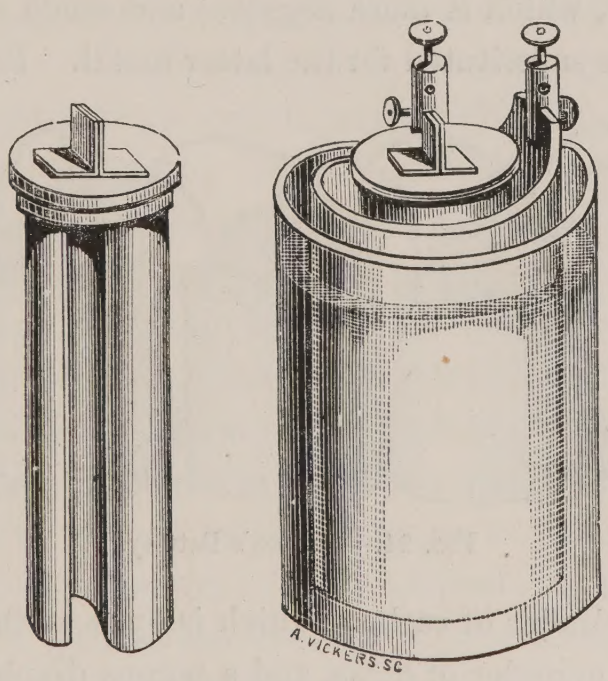

FIG. 23.—Grove's Battery.

placed by platinum, which forms the positive pole, and the solution of cupric sulphate by nitric acid. Amalgamated zinc is immersed in sulphuric acid diluted with ten times its bulk of water, and both liquids are separated by a porous diaphragm of unglazed porcelain. Nitric acid contains a large quantity of oxygen, whereby the intensity of the current is increased, and is a better conductor than cupric sulphate, so that the current is more easily transmitted. The hydrogen resulting from the decomposition of water is not set free upon the platinum, but changes nitric acid into

nitrous acid; while zinc is oxidised by the nascent oxygen, and sulphate of zinc remains in solution. The action of this battery is arrested in a comparatively short time by further chemical changes which take place in the nitric acid; copious red fumes are given off, which are most irritating to the air-passages, and at last the acid enters into ebullition. Grove's battery is therefore not suited for medical practice.

Bunsen's Battery differs from Grove's in this particular, that carbon, which is more negative and much cheaper than platinum, is substituted for the latter metal. In the original

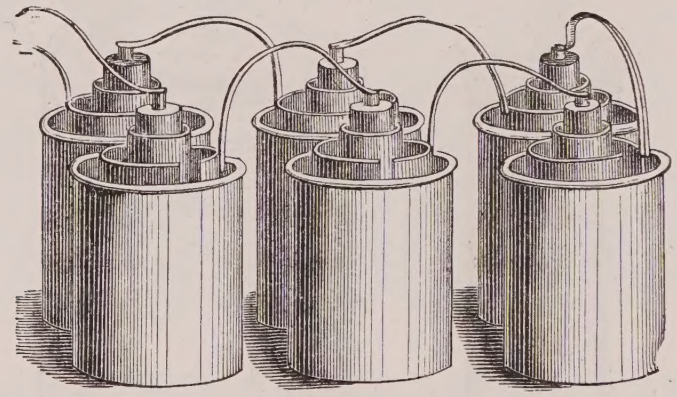

FIG. 24.—Bunsen's Battery.

battery a cylinder of carbon, which is open at the bottom, is placed in a cylinder of glass, and a porous diaphragm of unglazed porcelain, containing the zinc, is placed in the cylinder of carbon; nitric acid is then filled in between the glass and the carbon, and diluted sulphuric acid into the porous diaphragm containing the zinc. Bunsen's battery has lately been considerably modified, and constitutes now one of the most useful arrangements for medical practice. In this battery carbon is the positive, and zinc the negative pole.

In *Smee's pair*, plates of platinised silver or platinum are substituted for carbon. Metals are platinised by immersing them in a solution of chloride of platinum. Experience

shows that thereby the hydrogen is to a great extent prevented from adhering to the negative metals, so that polarisation is not so rapidly produced as it would be otherwise. Smee's pair has only one exciting liquid, viz., sulphuric acid diluted with seven parts of water, and is not nearly as constant as Daniell's. Silver is the positive, and zinc the negative pole of Smee's battery.

In *Boulay's battery* the copper is immersed, not in a solution of cupric sulphate, but in a solution of nitrate of potassium mixed with an equal quantity of cupric sulphate; while the zinc is immersed, not in diluted acid, but in a solution of chloride of sodium, mixed with an equal quantity of flower of sulphur. Both liquids are separated by a porous membrane. The chemical action which goes on in this battery is as follows:—Water is decomposed as usual, whereupon oxygen goes to the zinc to form zinc-oxide, and to the sodium to form protoxide of sodium; while chlorine goes to the zinc to form zinc-chloride. The hydrogen which is set free is attracted to the copper; but before it arrives there, it is met by the mixture of cupric sulphate and nitrate of potassium; cupric sulphate is decomposed as in Daniell's battery, the reduced copper being deposited on the copper pole. Oxygen and part of the sulphuric acid proceed towards the zinc, which they transform into zinc-sulphate; another portion of the sulphuric acid, however, combines with the protoxide of potassium of the nitre, forming sulphate of potassium, whereby a certain quantity of nitric acid is set free, which has considerable power as an electro-motor. According to M. Boulay this battery will remain in working condition for eighteen months consecutively, without there being any necessity to recharge it, and it is used for working the great organ of the church of Notre-Dame-de-Paris with satisfactory results.

Marié-Davy has invented four different kinds of constant batteries, viz., one with neutral sulphate of mercury, another with acid sulphate of mercury, a third with sulphate of lead, and a fourth with chloride of silver.

a. The *neutral sulphate of mercury battery* consists of carbon, C, immersed in a paste formed of the neutral sulphate, contained in a porous vase, D, and of an external cylinder of zinc, Z, which is contained in an external vase, V, surrounded by water. The neutral sulphate of mercury is by water resolved into a soluble acid salt, and an insoluble basic salt. From this the mercury passes off to the zinc, which is thus kept amalgamated. Oxygen and sulphuric acid are set free and combine with the zinc; but a portion of the oxygen unites with the nascent hydrogen to form water, metallic mercury and oxide of mercury being precipitated at the bottom of the porous vase.

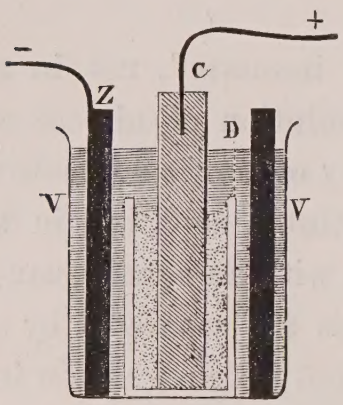

FIG. 25.

b. The *acid sulphate of mercury* battery is the same as the preceding one, only with this difference, that the acid salt is substituted for the neutral salt of mercury. The acid salt is not only easily soluble in water, but also contains more sulphuric acid than the neutral one, the formula for the former being $HgSO^4 + 2SO^3$, while that for the latter is $HgSO^4$. From this it results that the acid sulphate of mercury battery gives a stronger current than the neutral salt battery; on the other hand it is, just on account of this circumstance, not very constant.

c. The *sulphate of lead battery* consists of a zinc plate, Z, and a copper plate, C, separated by a porous vase, and immersed into a paste of sulphate of lead, to which some chloride of sodium has been added. Sulphate of lead is nearly insoluble in water, for at a temperature of 60°, not

less than 31,062 parts of water are required to dissolve one part of sulphate of lead. In consequence of this, the current furnished by this battery is very feeble, but very constant.

d. The *chloride of silver battery* was invented by Marié-Davy in 1859,[1] and it therefore appears singular that the credit of its construction, such as it is, should have been claimed nine years later by Dr. Warren de la Rue,[2] and M. Pincus,[3] of Königsberg. It consists of a rod of zinc (z) and

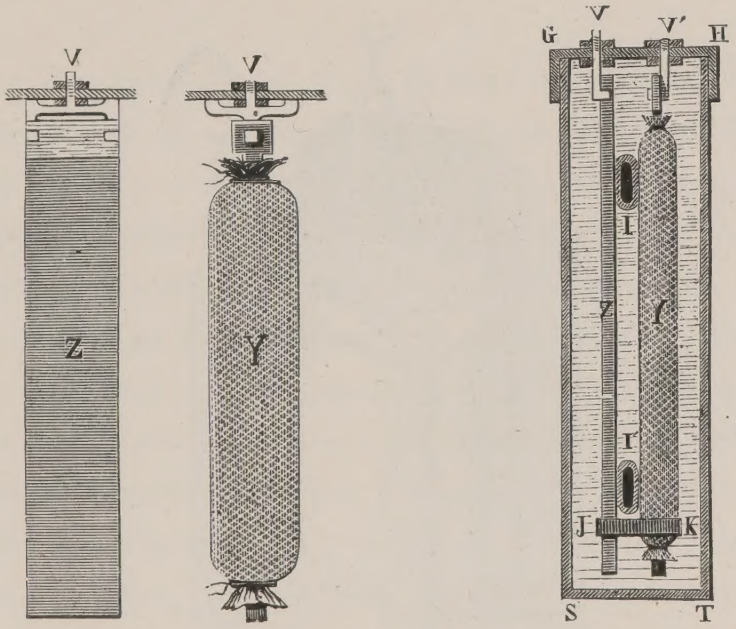

FIG. 26.—Chloride of Silver Battery.

a silver cup, or muslin bag, containing chloride of silver (Y), which is suspended on a silver wire, both being immersed into salt water or diluted sulphuric acid. Argentic chloride is a dark greyish powder, which is totally insoluble in water. It is, however, reduced by the nascent hydrogen, hydrochloric acid being formed and metallic silver being deposited in a finely pulverised state in the cup or bag. The action of the battery is arrested when all the chloride of silver has been reduced.

Amongst the more recently invented batteries, Leclanché's

[1] Comptes rendus, 1868, vol. lxvii. p. 794.
[2] Poggendorff's Annalen, vol. cxxxv. 1868, p. 167.
[3] Comptes rendus, vol. xlix. 1859.

has attracted a great deal of curiosity and attention. There can be no doubt that Leclanché's arrangement is the most constant which is known, as far as the length of time is concerned during which action is still perceptible. During our recent stay in Paris, M. Tripier showed us a Leclanché, which had been charged four years ago, and had never been touched since, but which still gave signs of considerable galvanic activity. The Leclanché pair consists of a cylinder of zinc

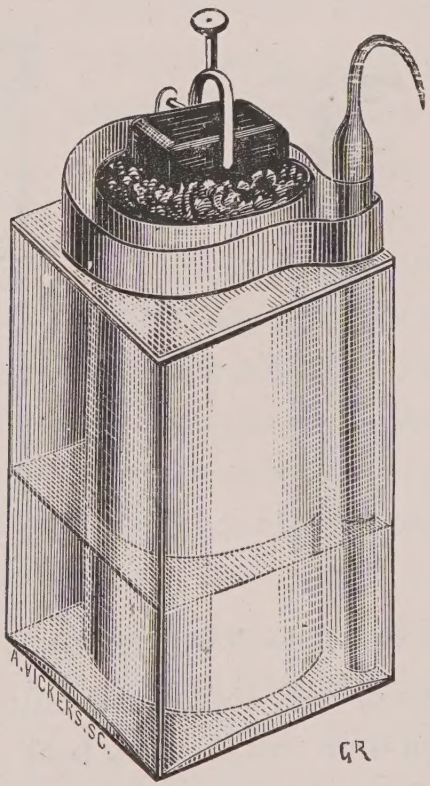

FIG. 27.—Leclanché's Battery.

immersed in a concentrated solution of chloride of ammonium, and a rod of gas-carbon packed with coarsely powdered gas-carbon and small pieces of pyrolusite (native peroxide of manganese) in a porous cell. The vase is closed with a cover, through which the rod of carbon may pass, and which has two small openings for allowing the access of air and the escape of the hydrogen and ammonia formed by the electrolytic action of the battery. The chemical process which takes place in Leclanché's pair is therefore the fol-

lowing: the solution of chloride of ammonium is decomposed, chlorine combines with the zinc, hydrogen is absorbed by the oxygen of the pyrolusite, and ammonia is set free. This is at first absorbed by the water; but, as soon as the water is saturated with it, the ammonia escapes into the atmosphere through the apertures of the cover. Leclanché's pair gives an abundant supply of electricity. According to Beetz, its electro-motor power is 1.167, Daniell's power being put at 1.

Prince Bagration's constant battery consists of zinc and copper immersed in a vase filled with earth, which latter is moistened with a solution of chloride of ammonium.

The Water Battery.—Extensive water batteries have been constructed by Messrs. Crosse, Noad, and Gassiot. Crosse's battery consists of 2,500 copper and zinc cylinders, immersed in water, enclosed in glass jars, insulated on glass stands, and well protected from dust and light. Thirty of these pairs give a slight spark; 130 open the gold leaves of the electrometer about half an inch; 250 cause the gold leaves to strike their sides; 500 slightly cauterise the skin; 1,200 give a powerful shock. When the opposite poles of 2,400 pairs are connected with the inner and outer coatings of a battery of Leyden jars, a continual charge is kept up, each discharge being accompanied with a loud report which may be heard at a considerable distance. The discharges pierce stout leather paper and deflagrate silver leaf, while light substances are attracted from a distance of some inches. Gassiot's water battery is even more powerful, and consists of 3,520 pairs of zinc and copper cylinders.

These batteries require nothing but the addition of ordinary water to make up for that which is lost by evaporation, and will keep in good condition for years. They are, however, totally unfit for medical use, partly because they take up a very large space and are very troublesome to build

up, and partly because their electrolytic and catalytic effects are very insignificant, owing to the bad conducting power of the water. The current has therefore to overcome an immense resistance in order to arrive at the poles; and thus by far the largest portion of the electricity that is developed is checked in its passage, while the small quantity which passes is in a high state of tension. For medical use, however, just the opposite is required, viz. a large quantity and comparatively little tension.

The constant batteries, arranged for medical use, will be described in the third chapter.

A combination of two metals immersed in or moistened by a liquid, is called an *open circuit*. The circuit is *closed* if the two metals be connected, apart from the liquid, by means of a metal wire, which latter is called the *conjunctive wire* or *arch*. This wire is a better conductor of electricity than the liquid, and the two contrary electricities, therefore, which are liberated by the electro-motive force, travel towards each other through this wire to neutralise each other. The production of electricity in a galvanic pair being continuous, the conjunctive wire is therefore traversed by a *continuous galvanic current*, as long as any chemical action takes place in the pair.

Any current furnished by a galvanic battery, without the intervention of a coil of wires and a magnet, is a *continuous* current; but a *constant* current is only that kind of continuous current which is furnished by the *constant* batteries. Thus, the old voltaic pile furnishes a continuous, but not a constant, current; whilst Daniell's and Bunsen's batteries yield a constant current, which of course is at the same time continuous.

Direction of the Current.—In each galvanic pair there are two currents, viz. a positive one travelling towards the negative pole, and a negative one travelling towards the

positive pole. In order to avoid mistakes, however, it has been generally agreed to take only the positive current into consideration. The easiest way to show the direction of the current in any galvanic battery, is to electrolyse water. The positive pole is that one where a copper wire becomes oxidised and loses its brightness; and the negative pole is that one where the metallic lustre remains, and bubbles of hydrogen gas are seen to rise.

Derived Currents.—If in a closed circuit two points be connected by an additional conductor, a portion of the current is drawn off or 'derived' by the latter. The current, as it existed before the derivation was established, is termed the *primitive current*; the additional conductor, *derivation wire*, and the portion of the current that passes by this wire, the *derived current*. The intensity of a derived current is, of course, much more feeble than that of the primitive current.

Electrolysis.—Nicholson and Carlisle discovered, in 1800, that a voltaic current may decompose water at a distance from its place of generation. When the conducting wires of the voltaic pile are immersed in a vessel containing water, it is found that the quantity of water is gradually diminished, and that oxygen is attracted to the positive pole, where the current enters, while hydrogen appears at the negative pole, where the current leaves the liquid. Again, if a solution of table-salt be subjected to the action of the current, not only the water, but also the chloride of sodium, are decomposed; and chlorine and oxygen accumulate at the positive, while hydrogen and sodium go to the negative pole. A piece of blue litmus-paper immersed into the solution, will facilitate the discovery of the direction of the current; at the negative pole, where alkalies appear, the blue colour will be rendered more intense; while at the positive pole, where acids are set free, the paper is reddened. If a solution

of potassic iodide and starch be brought under the influence of the current, a blue colour will appear at the positive pole where iodine is set free, while at the negative pole the solution remains colourless. By using this decomposing power of the voltaic current, Sir Humphry Davy made, in 1807, his great discoveries concerning the chemical composition of the fixed alkalies, which he resolved into metals and oxygen. Faraday afterwards thoroughly investigated the whole subject, and proposed the following terms in connexion with it:—*Electrolysis* means electro-chemical decomposition, as distinguished from analysis, or ordinary chemical decomposition. *Electrolytes* are chemical compounds which may be decomposed by electricity; *electrodes* (ways of electricity) are the extremities of the metallic conductors through which the current enters into, and passes out of, the electrolyte. The positive electrode is the *anode*, and the negative the *cathode*. The elements which appear at the electrodes, are *ions*; those which follow the direction of the current of positive electricity, and are evolved at the cathode, such as hydrogen, the metals, and the basic radicles generally, are *cations* or electro-positive bodies; while those which travel in the direction of the current of negative electricity, and are evolved at the anode—such as oxygen, chlorine, iodine, bromine—and acid radicles generally, are *anions* or electro-negative bodies. The electrolytic effect increases in proportion to the surface of the metals, and the number of pairs of which the battery is composed.

Substances which consist of one equivalent of one element, and of two or more equivalents of another element, are no electrolytes. Chlorides, for instance, such as chloride of sodium or potassium, can be easily decomposed; while perchlorides, such as the perchloride of platinum, resist the electro-chemical decomposition. Sulphuric acid, nitric acid, and ammonia, are no electrolytes, for the same reason, but

they may be decomposed if water be added to them. Thus, for instance, if diluted nitric acid be subjected to the action of the current, the water is decomposed; and hydrogen, which is developed at the negative pole, combines with part of the oxygen contained in the nitric acid, to form water and nitrous acid; while oxygen appears at the positive pole. In the same manner, diluted ammonia may be decomposed, as oxygen which is liberated at the positive pole combines with the hydrogen of the ammonia to form water, whereby nitrogen is set free. This is, however, not direct, but *secondary electrolysis.*

On the whole, very few chemical compounds can transmit a galvanic current without being decomposed by it; but in order to be electrolysed, the smallest particles of these bodies must be freely movable in all directions, so as to be able to obey the laws of electrical attraction and repulsion; and they must therefore be gases, liquids, or semi-solids.

In 1866 and 1867, I made a series of microscopical observations on the changes which animal structures undergo, under the influence of the electrolytic action of the galvanic current. This department of microscopical research had before then been quite neglected; and knowing the powerful electrolytic effects of the constant battery, I expected to arrive at some curious results in undertaking these investigations.

I have studied the action of the current upon the intimate structure of the skin and cellular tissue, muscular fibres and tendons, cartilages and bones, liver and pancreas, spleen and thyroid body, kidneys and suprarenal capsules, testicles, breasts and ovaries. The general result of these investigations has been *that no animal tissue whatever can withstand the disintegrating effect of the negative pole, and that the force and rapidity with which this disintegration*

is brought about are directly proportional to the electromotive force which is employed, and to the softness and vascularity of the structures acted upon. Thus ten cells of a battery have a more thorough and rapid effect than five, fifteen more than ten, and so on; while, as regards the tissues, those containing most water, such as the muscles, the cellular tissue, the spleen, &c., are more rapidly disintegrated than those which contain less fluid. Bones and teeth withstand the action of the current for a considerable time.

A curious and novel circumstance forced itself early on my

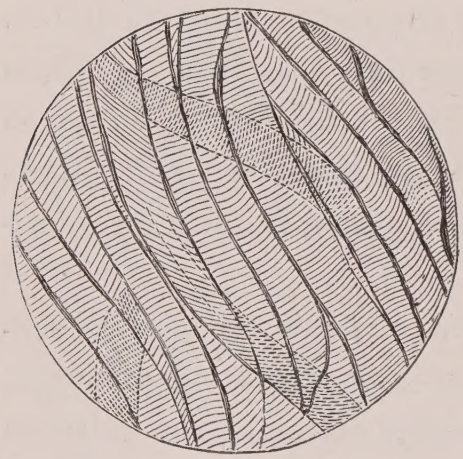

FIG. 28.—Muscular fibres before electrolysis. 200 ×.

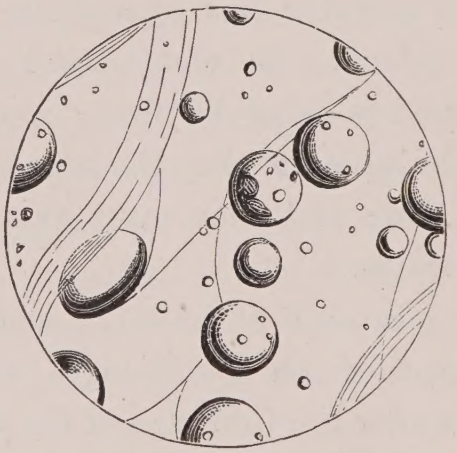

FIG. 29.—The same after two minutes electrolysis. 200. ×.

attention; and this was, that the electrolytic effect of the negative pole on animal tissues was mainly composed of two different elements, viz. of the mechanical action of the nascent hydrogen, which was, under the microscope, seen to rise in innumerable bubbles as soon as the circuit was closed, and to force itself, as it were, between the structural elements of the tissues, driving their fibres mechanically asunder; and secondly, of the chemical action of the alkalies, soda, potash, and lime, which, together with hydrogen, are developed at the negative pole of the battery.

No galvanic heat is produced if the current be applied in

such a manner that the whole body, or part of the body, or animal liquids, are placed within the circuit of the battery; as is done, for instance, if a needle connected with the negative pole is inserted into the depth of a tumour, while a moistened conductor connected with the positive pole is placed outside on the skin. This is proved by the following experiment:—I immersed the two electrodes at a certain distance from each other, into blood, thus letting the current travel from the positive to the negative pole, and *vice versa*, and I then read off the temperature at the poles as well as in the liquid itself, on a Negretti and Zambra's thermometer, the bulb of which was in the liquid, and which allows variations of one-tenth of a degree of Fahrenheit to be distinctly ascertained. It was seen that whether I used five, ten, fifteen, twenty, or fifty cells of the battery, no elevation of temperature took place. The effects of a current administered in this way are therefore simply electrolytic, and have nothing to do with the galvanic cautery.

Seeing that such powerful effects were produced at the negative pole on dead organic structures, I was naturally anxious to enquire what would be the effect of the same in the living body. Having procured some *corpora vilia*, viz. frogs and rabbits, I found that the effects were, to a certain extent, identical with those obtained on dead tissues; only with this difference, that in the warm-blooded animal the action was more rapid and energetic, which is explained by the fact that water at a temperature of 98° conducts electricity better than water at 60°. While, however, the immediate effects of the current were nearly the same in dead and living structures, considerable changes in the nutrition of the parts were observed as proximate and remote sequelæ of such operations in living animals.

It was then observed that needles connected with the negative pole of the battery could be inserted into, and re-

moved from, the body without causing any loss of blood; that the current used did not appear to give much pain to the animal beyond what was due to the introduction of the needles to the skin; and that the parts operated upon shrank sensibly after the operation, but that there was neither inflammation, suppuration, nor sloughing. If the current was made to act upon blood-vessels, it was found that they were filled with a foreign body, due to disintegration of the blood, and round which afterwards a slow deposition of lamellated fibrine took place; they were thus changed into solid strings wherever the current had been made to act. It appeared fair to conclude from these observations, that the current could be safely and successfully applied to such parts of the body where shrinking and disintegration of tissue and obliteration of blood-vessels might be required for surgical purposes.

The sores which are produced in the skin by the negative pole resemble those caused by caustic potash; and the same may be said of the cicatrices, for these latter have no tendency to contract, but are soft and become gradually similar to the surrounding skin, so that after some time no scar is perceptible, unless the action was originally very prolonged and very powerful.

The immediate effect of the electrolytic decomposition of any animal liquid is, that the anode is oxidised and chlorinated, and from a metal changed into a metallic salt, since no metal can resist the effects of oxygen and chlorine in their nascent condition. On the other hand, metals are not changed by hydrogen or free alkali, and the cathode therefore retains its bright metallic aspect, whatever may be the power of the current used, or the length of time during which the action is kept up. In using the cathode, therefore, we do not introduce any foreign substance into the liquid, but only alter its composition; while, by using the

anode, we may introduce into it salts of iron, copper, silver, gold, or any other metals used as directors, and which combine with the albumen to form albuminates.

The following phenomena are observed when the albumen of an egg is subjected to electrolysis :—On immersing a steel needle connected with the cathode, and another steel needle connected with the anode, into the liquid, a peculiar substance is formed round the cathode, which at first sight looks like a coagulum or clot, but is in reality no clot, but a sort of lace-like jelly-froth, which consists of the smallest particles of albumen, mechanically disintegrated by the nascent hydrogen, and chemically altered by the evolution of free alkali, the presence of which may be shown by its effects on litmus and turmeric-paper. The principal salines found in the egg-albumen are the chlorides, sulphates, and phosphates of soda, potash and lime. These are decomposed; hydrochloric, sulphuric and phosphoric acid appearing at the positive pole, while soda, potash and lime are set free at the negative pole. An entirely different effect from that at the cathode is therefore produced at the anode, where the steel needle is oxidised; and by the development of chlorine and of sulphuric and phosphoric acid, sulphate, phosphate, and chloride of iron are formed. These salts impart a reddish-brown colour to the albumen, with which they form an organic compound.

On substituting gold needles for steel needles at both poles, we perceive that the effect at the cathode is exactly the same as that produced with the steel needle, while at the anode different phenomena present themselves; for there we have no longer chloride and sulphate of iron, but perchloride of gold, by which a greenish-blue clot is produced. If the nature of the positive pole be once more changed by substituting a brass or copper wire for the steel or gold needle, the effect is again different at the anode,

where a whitish clot is formed, owing to the action of the copper-salt on albumen, while at the cathode things look as before.

The effects of the continuous current on the albumen of an egg are therefore twofold; viz. first, mechanical disintegration of its substance by the nascent hydrogen, and chemical alteration by caustic alkalies at the negative pole; and, on the other hand, chemical alteration by chlorine and acids at the positive pole. There is in such experiments no visible development of oxygen gas at the positive pole, because the oxygen that is evolved at once combines with the metals. This is the reason why, after such experiments, the gold needle appears black, the steel needle brown, and the brass wire greenish-black; while at the negative pole no alteration of the metals is observed.

The effects of the continuous current on blood resemble those produced on albumen, but are, of course, modified by the presence, in the former liquid, of fibrine, hæmatine and iron. This is the reason why coagulation takes place at both poles, with only this difference, that the negative clot is red, soft, and bulky, while the positive clot is dark, hard, and small. Both clots remain unchanged for several days, and are only dissolved when putrefaction of the animal liquid commences. The clots formed in arterial blood are firmer and less dark than the clots formed in venous blood. The effects are otherwise the same, whether the blood has been taken from arteries, veins, or capillary vessels, and is experimented upon in a cup, or whether it is still circulating.

Unpolarisable Electrodes.—A necessary consequence of the fact that the continuous current cannot traverse an electrolyte liquid without decomposing it, is, that the surface of the electrodes immersed in such a liquid becomes covered with deposits, either gaseous or solid. Thus, if copper wires be immersed in a solution of table-salt, bubbles of hydrogen

are seen to encircle the negative wire, while the positive wire is oxidised by the oxygen developed. The liquid then exercises a chemical action on the deposits with which the surfaces of the electrodes are covered; and thus secondary currents are produced. Electrodes are called polarised, if they develop a secondary current in consequence of having been traversed by a primary current. Polarisation of the electrodes has offered considerable impediments to the study not only of animal electricity, but also of the physiological action of artificial electricity upon the animal tissues. It may be to some extent prevented by frequently wiping the electrodes, but is completely avoided only by using for the conveyance of the current pieces of pure zinc immersed in a solution of sulphate of zinc in equal parts of water. This was discovered by M. Regnauld.[1] Matteucci[2] afterwards found that the common zinc of commerce, if properly amalgamated, has the same property. Du Bois-Reymond[3] has shown that copper immersed into a concentrated solution of cupric sulphate is nearly unpolarisable, but is not so homogeneous as amalgamated zinc; and that zinc is also unpolarisable if immersed into a syrupy solution of chloride of zinc.

Electric Endosmosis.—M. Reuss, of Moscow, has discovered that when a porous diaphragm is placed in a liquid traversed by a continuous current, the liquid will pass through the diaphragm in the direction of the positive current. M. Porret has called this process 'electric endosmosis,' and it has been studied chiefly by Heidenhain, Jürgensen, Wiedemann, and Quincke. The latter found that with a feeble current there are two modes of propagation of solid particles which are suspended in liquids: the particles near the sides of the tube move towards the positive pole, and those in the

[1] Comptes rendus, 1854, p. 891. [2] *Ibid.* 1856, p. 1054.
[3] Monatsberichte der Berliner Akademie, 1859.

centre of the tube move towards the negative pole. By increasing the intensity of the current, the particles in the centre are caused to move more rapidly towards the negative pole, while those near the sides move partly towards the negative, and partly towards the positive pole; the larger ones taking the direction towards the positive, and the smaller towards the negative pole. By further increasing the intensity of the current, all particles are made to move towards the negative pole, whatever may be their size or position.

Galvanometer.—The quantity of electricity evolved by a galvanic pair may be measured by the quantity of hydrogen

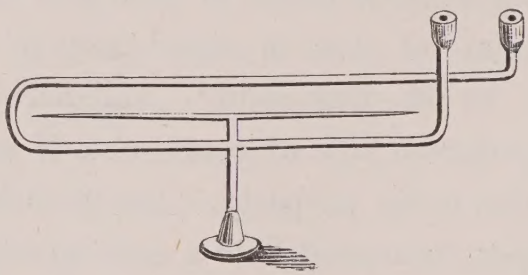

FIG. 30.—The Galvanometer.

and oxygen evolved electrolytically in a given space of time. But the magnetic, calorific, and other effects of the current, are not proportional to its chemical power; and, for measuring these accurately and quickly, it is necessary to have recourse to the magnetic action itself. This is done by employing a galvanometer. The ordinary galvanometer consists of a magnetic needle, placed between the two arms of the conducting wire of the battery bent back upon itself. As long as no current passes through the wire, the needle remains quiescent, but is deflected on closing the circuit. The angle of deflection obtained is, to some extent, proportionate to the intensity of the current; but this instrument is really not much more than a galvanoscope. It is true that it will indicate the existence of a very feeble

current, and also give an approximative indication of its strength by the magnitude of the angle to which it is deflected; but the latter is not really proportionate to the strength of the current. For accurate measurement, therefore, the *tangent galvanometer* or *tangent compass* is required. Fig. 31 represents the tangent galvanometer which I use in connection with Muirhead-Daniell's battery. The current is here made to pass through a broad circular band of copper, in the centre of which is the magnetic needle. The length of the needle is so proportioned to the diameter

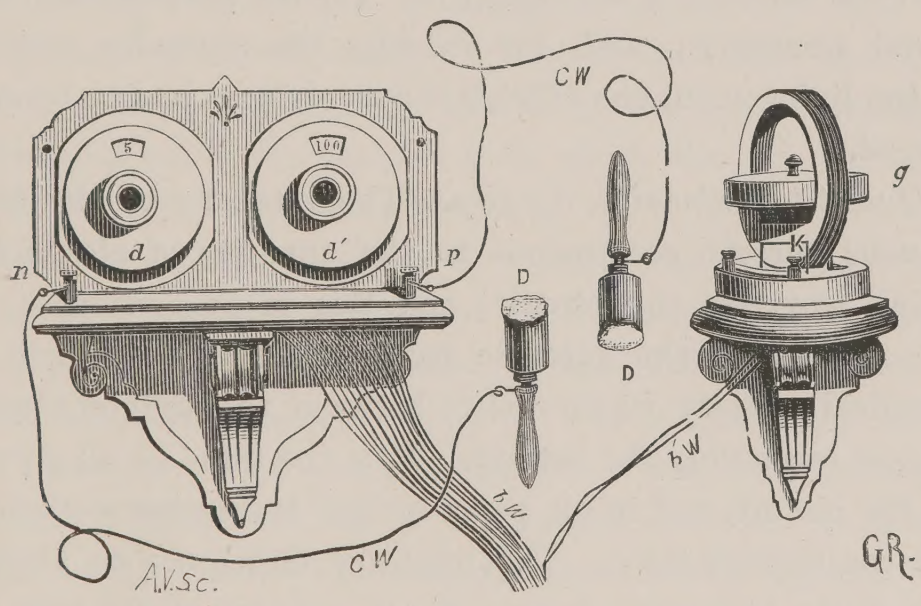

FIG. 31.—Pole-board of Muirhead-Daniell's battery as used by the author.

of the band that the distance of the end of the needle from the band, and consequently the action of the current upon it, is the same at all angles of deflection. This instrument is so placed that the plane of the band coincides with the magnetic meridian.

Multiplier.—A very feeble current does not cause a deflection unless its action on the magnet be increased; this may be done by coiling the wire several times round the needle, and insulating it so that the current cannot pass directly through the whole mass, but has to traverse the

circuitous route of the coil. The more numerous the convolutions of the wire, the greater is the action of the current upon the needle. A contrivance of this kind has been termed a *multiplier*, as it multiplies the effects of the galvanic current. This instrument was invented by Schweigger, and first employed in electro-physiological researches by M. Nobili. Du Bois-Reymond has constructed multipliers of the utmost sensitiveness, by means of which he was enabled to detect the presence of electric currents in almost all the tissues of the animal body. For showing the nervous current, a multiplier of 11,000 convolutions was found necessary; and, for showing the muscular current in the living man, one of 24,000 convolutions had to be employed.

Quantity, intensity, density.—The intensity of the continuous current corresponds to the quantity of electricity which traverses the circuit; and this is proportionate to the surface of the galvanic pair, and to the degree of chemical affinity which exists between the different substances composing the battery. It is the same in all points of the circuit, and in all parts of the transverse section of the conjunctive wire. The intensity undergoes no alteration if the transverse section of one portion of the wire be diminished; but the electricity which moves within a given space of time through a reduced transverse section of the wire, must be in a state of greater *density* than that passing through the larger transverse section of the wire. Thus, if I denotes the intensity of the current, D its density, and T the transverse section of the conjunctive wire, the formula $D = \frac{I}{T}$ will be obtained, that is to say, the density of the electricity is equal to the intensity of the current divided by the transverse section of the conjunctive wire.

Resistance; Conducting Power.—We have seen that

when the poles of a pair are connected by a conjunctive wire, the two contrary electricities, which are liberated by the electro-motive force, travel towards each other to neutralise each other; but in no battery do we ever obtain, in the form of a current, the whole amount of electricity that is produced by the chemical action of the substances in circuit; since the quantity of electricity in circulation must be always less than that which would traverse a perfectly-conducting conjunctive wire. While, therefore, the quantity of electricity *produced* depends upon the intensity of the electro-motive force, the quantity of electricity that is *travelling*, and may be collected, depends upon the resistance offered to the passage of the electricity through conducting bodies, and upon the tension with which the electricity is driven through the conjunctive wire.

All bodies through which an electric current is propagated offer a certain resistance to its passage, and consequently diminish its intensity. *There are no absolutely perfect conductors of electricity.* If the magnetised needle of a galvanometer be brought into the circuit of a battery, it suffers a deflection; but if we interpose between the poles copper or silver wires, which are the best electric conductors, the deflection of the needle appears less considerable than before; showing that the power of the current has been diminished by their interposition.

Ohm's Law.—Professor Ohm, of Nuremberg, has mathematically investigated the circumstances which influence the quantity of electricity that may be obtained from a galvanic circuit, and has established the law, *that the intensity of the current is directly proportional to the electro-motive force, and inversely proportional to the resistance*; this is equivalent to saying that the *intensity of the current is directly proportional to the electro-motive force divided by the resistance.* Thus, if I denotes intensity, E the

electromotive force, and R the resistance, the following formula is obtained : $I = \frac{E}{R}$.

The resistance of a galvanic battery consists of two parts, viz. that of the pair itself, which is called *internal* or *essential* resistance ; and that of the conjunctive wire, which is called the *external* or *non-essential* resistance. Internal resistance is that which the voltaic current experiences in forcing its way through the battery itself, and external resistance that which is offered by the external conductor which joins the two poles. The latter consists either entirely of metal, or partly of metal and partly of electrolytic liquids, such as water, a solution of chloride of sodium, &c. If we now put R as essential resistance, and r as non-essential resistance, the following formula is obtained :

$$I = \frac{E}{R+r}.$$

In a battery consisting of a considerable number of pairs, the electro-motive force becomes nE, and the internal resistance nR. Now, supposing the external resistance of the wire on the electrolytic liquids to remain the same as before, we obtain the third formula :

$$I = \frac{nE}{nR+r}.$$

If r be small, as when the circuit is closed by a short and thick wire, the quantity of electricity developed by n cells is the same as that which is set free by a single pair of the same size. But when r is considerable, as when the circuit be closed by more imperfect conductors, such as a long and fine wire, or electrolyte liquids, the intensity of the current increases proportionately to the number of pairs. These theoretical considerations are of importance, because we shall see presently that *the human body must, as far as*

conduction is concerned, be looked upon as an electrolyte liquid.

The intensity of the galvanic current can be increased or diminished by altering E, R and r. E may be increased by selecting metals as far as possible removed from each other in their polarity; R may be increased by increasing the length of the metals composing the pair and the length of the liquid contained in the cell; and it may be diminished by increasing the transverse section of the pair, and by selecting particularly well-conducting liquids for exciting the action of the pair. Finally r may be increased by using long and fine wires of imperfectly-conducting metals, or electrolyte liquids; and it may be diminished by using short and thick wires of well-conducting metals. Where therefore, the resistance of animal tissues or liquids has to be overcome, we must use a considerable number of pairs of moderate size, containing a well-conducting liquid, and conducting wires of silver or copper, of moderate length, and a somewhat considerable transverse section. This is the case when we use the constant current in medicine, for percutaneous applications to the nervous centres, and the peripheral nerves and muscles, and likewise for the electrolysis of tumours. On the other hand, totally different arrangements must be made for using the galvanic cautery. There it is necessary to increase the resistance, and we therefore use a few very large cells, and select a conducting wire of somewhat low conducting power, viz. platinum, which may be easily rendered incandescent by the current, and has then the same effect as the actual cautery.

The resistance of bodies varies according to their chemical nature, temperature, and form. Resin, glass, and sulphur are the worst, and metals the best conductors. Of the latter silver is the best, and mercury the worst; after silver ranks copper, which conducts better than gold; gold conducts

better than iron; iron better than platinum; platinum better than lead. The resistance is especially great if the current pass from a liquid to a solid, or from a solid to a liquid. Liquids conduct much worse than metals; but elevation of temperature increases their conducting power, whilst heat diminishes the conductivity of metals. The resistance offered by a concentrated solution of cupric sulphate to the passage of the current is sixteen million times greater than that offered to it by metallic copper; and the resistance of distilled water is four hundred times greater than that offered by the solution of cupric sulphate. Therefore a current will pass more easily through a copper wire ten thousand miles long than through a layer of water one inch long.

The following table shows the resistance of some of the substances which are generally used in electrical observations, their temperature, length, and transverse section being the same.

Silver	1·000
Chemically pure copper	1·065
Commercial copper	1·270
Brass	5·372
Iron	6·767
Platinum	9·590
Mercury	29·238
Sulphuric acid	761,732·000
A solution of cupric sulphate, containing 20 per cent. of the salt	14,809,000·000

The conducting power of bodies does not only depend upon their chemical nature and temperature, but also upon their form. If an electric current of the same intensity be made to pass through wires of the same metal and diameters but of different length, we find that it loses power in proportion to the length of the wires through which it is caused to pass. If, on the other hand, the current be sent through wires of the same metal and length, but of different diameter, its power is increased in proportion to the diameter of the

wires. Thus, for instance, a copper wire a hundred feet long and the twelfth of an inch in diameter, offers the same resistance as a copper wire two hundred feet long and a sixth of an inch in diameter. Again, the resistance offered by the arm of a man is nearly the same as that offered by the leg; since both the length and the diameter of the leg are nearly double those of the arm.

An important instrument for measuring the resistance of conductors is the *rheostat* or *current-regulator*. A variety of such instruments have been constructed, but they all have one feature in common, and that is, that a conducting wire is introduced into the circuit, the length of which may be varied at pleasure, without making any alteration in the rest of the circuit.

Professor Wheatstone has constructed two rheostats, one for strong, and another for feeble resistances. The one for

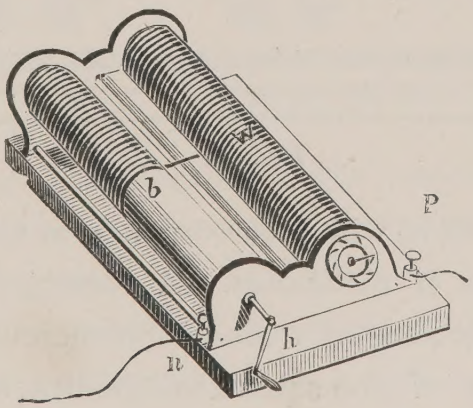

FIG. 32.

strong resistances consists of two cylinders, *b*, *w*, placed with their axes parallel to each. The cylinder *w* is made of wood, and is furnished with a fine screw, around which is coiled a fine brass wire; *b* is a cylinder made of brass, and is connected with one end of the wire, the other end of which is connected with a brass ring fixed to the wooden cylinder. On the wood the wire is insulated, as dry wood is no conductor, while on the brass cylinder it is not insulated. The

battery current enters at p, n, and a movable handle h, serves to turn the cylinders alternately round their axes.

If b is turned to the right, the wire is uncoiled from w, and coiled upon b; and if w is turned to the left, the reverse takes place. The number of coils are indicated by a scale; and in proportion to the number of turns which the wire makes round the insulating wooden cylinder, the journey of the current will be longer, and the resistance greater.

The rheostat chiefly used in the medical application of electricity is Siemens's. This consists of a number of coils

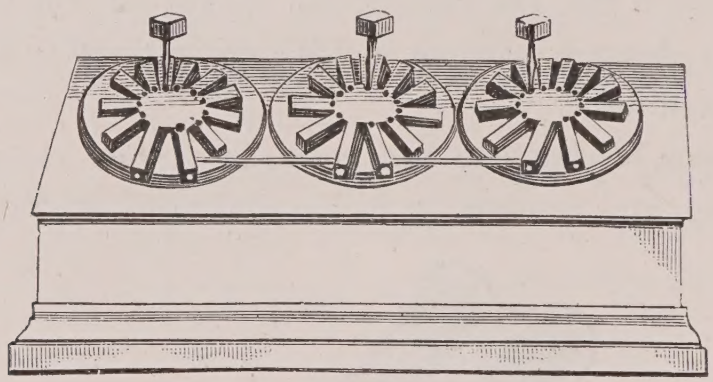

FIG. 33.

of wire, the length of which corresponds to a certain number of Siemens's units of resistance. A Siemens's unit is equivalent to the resistance of a column of mercury which has a transverse section of one square millimètre, and is one mètre long, at 32° F. It may contain a variable number of units. Brenner, who was the first to use the rheostat in medicine, employs one of 2,100 units, but one with 1,110 is sufficient for most scientific and practical purposes.

The metal blocks 1, 2, 3, &c., 10, 20, 30, &c., and 100, 200, 300, &c., are connected with insulated coils of wire, the length of which corresponds to 1, 2, 3, &c., 10, 20, 30, &c., 100, 200, 300, &c. M, M′, M″, are brass plates which are furnished with semi-circular incisions for receiving a stopper, by means of which the blocks are connected with the centre-

piece, and with the pieces *c*, *e*, and *g*, which can be interpolated into the circuit. If the three stoppers are inserted into the blocks *b*, *d*, and *f*, there is no resistance at all in the rheostat, as the current travels from *a* to *b*, then through the stopper to M, and through *c* to *d*; from *d* it goes to M′ and *e*; from *e* to *f*, M″ and *g*; at *h* the current leaves the instrument altogether. With this arrangement the current does not encounter any resistance in the rheostat, and therefore goes altogether through it, and not through the body at all; for it is a fundamental law, that when the current has two

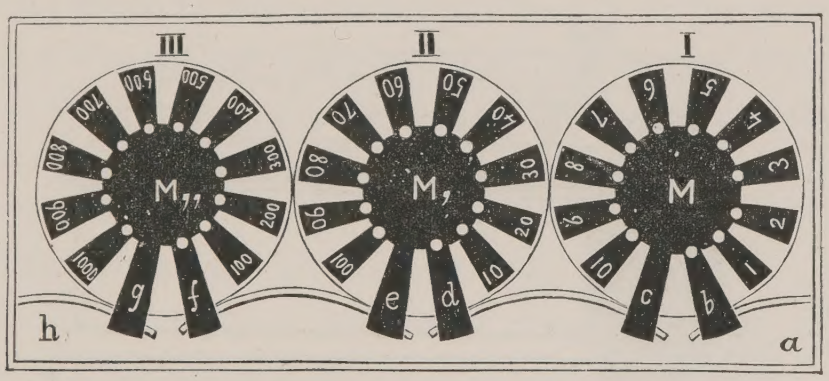

FIG. 34.

ways open to it, the intensity of the current in the several parts of the circuit is inversely proportional to the resistance. The greater the resistance in the rheostat, the greater is the intensity of the current going through the body; the smaller the resistance of the rheostat, the smaller is the intensity of the current going through the patient.

If now the stoppers are inserted at 1 in M, 30 in M′, and 300 in M″, the current which enters at *a*, has to proceed through the resistance 1 to M; thence it passes from *c* to *d*, and encounters fresh resistances, as it has to reach M′ through the coils 10 and 20; from *e* it goes to *f*; but before reaching M″, it must again pass through the coils 100, 200, 300, and then at last it may leave the rheostat by *g* and *h*. The result is, that the current has had to overcome the resistance of 321 Siemens's units, and a large portion of it therefore goes

preferably through the body. If the maximum of resistances be interpolated, only a very small portion of the current may go through the rheostat, and by far the largest portion of it will pass through the body. If the stoppers are entirely removed, the conduction is interrupted, and not a fraction of the current may then go through the rheostat.

Messrs. Mayer and Wolff,[1] of Vienna, have constructed a somewhat more simple arrangement. This consists of a wooden box, which contains coils of wire corresponding to 1,605 Siemens's units. The lid of the box carries a brass

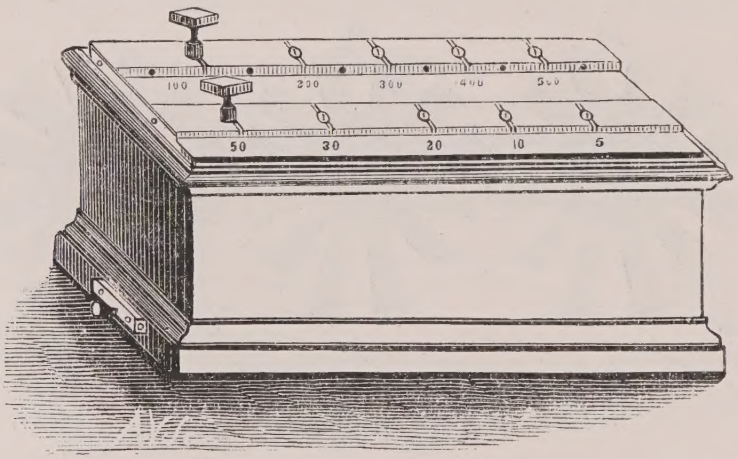

FIG. 35.—Mayer and Wolff's Rheostat.

plate with incisions, into which the stoppers are inserted. For interpolating any number of units which may be required, the stoppers are removed from the opening. Thus, if the current be required to pass through ten units, the stopper is withdrawn at 10; if required to pass through twenty-five units, the one at 5 and the one at 20 are removed; if required to pass through fifteen hundred units, the stoppers at 500, 400, 300, 200, and 100 are taken out.

No other instrument but the rheostat can yield such a variety of graduations, or, as I would prefer to call it, *shades* of the intensity of the current. The rheostat is not always

[1] Rosenthal's Electrotherapie. Wien, 1873, p. 35.

necessary for peripheral applications of the continuous current; but where the latter is to be used in the diagnosis or treatment of diseases of the nervous centres, and of the organs of special sense, the rheostat becomes an indispensable contrivance, without which the application of electricity ceases to be scientific.

Duchenne[1] has recommended the use of a *rheostat-voltameter*, which he thinks is likely to supersede Siemens's rheostat. He admits that the latter is more sensitive, but believes that such great precision is not required in therapeutics. Such an extraordinary profession on the part of an observer who may be justly proud of the precision with which most of his own investigations have been made, must needs excite our surprise. The 'liquid-rheostat' consists of a glass tube closed by a metallic bottom beneath, and above by a ferrule through which a metallic stem passes, which latter may be more or less driven down into the tube by means of a rack, which is put in motion by a button. The tube is filled with water, and both ends are enclosed in the circuit of the battery; the resistance offered to the current by the layer of water which it has to traverse, being less in proportion as the stem is further driven down into the tube. With this tube Duchenne associates a voltameter, that is, a tube 4 or 5 inches long, which is closed beneath by putty, through which two platinum wires are made to pass which are insulated from one another, and which may be connected with the conducting wires of the battery. If this tube be filled with water, and put into the galvanic circuit, the water is decomposed, and the quantity of gas which is evolved during the passage of the current is the expression of the electrolytic power of the current.

Duchenne connects the liquid rheostat with the voltameter

[1] Archives générales de médecine, mars 1873.

in the following manner:—They are fixed on the same wooden support, and one of the platinum wires of the voltameter is made to communicate with the metallic bottom of the rheostat. The upper end of this and the second wire of the voltameter may be connected with the poles of any battery. Now supposing that the rheostat-voltameter is placed into the circuit, and that the metallic stem of the graduating tube is in contact with the bottom of the latter, the intensity of the current will be indicated by the development of a large quantity of gas. But if, on the other hand, the stem be removed from the metallic bottom, the evolution of gas diminishes in proportion as the size of the layer of water traversed by the current diminishes. No doubt this arrangement of Duchenne's may be serviceable for a rough and ready graduation of the current, but it can never replace either Siemens's or Mayer and Wolff's rheostat.

Conductivity of the Human Body.—Volta, Humboldt[1] and Ritter,[2] who were the first to give their attention to this subject, found that the human body conducted not nearly as well as the metals, and that the cuticle, hair and nails, offered the greatest resistance to the passage of electricity. Professor E. Weber[3] put the conducting power of the body as ten to twenty times greater than distilled water at 98°, and fifty million times worse than copper. He found the resistance greatest where the skin is thick and dry, and least where it is thin and moist; and noticed that the mucous membranes conduct better than the skin, and that the resistance of the body is essentially diminished by

[1] Versuche über die gereizte Muskel- und Nervenfaser. Posen und Berlin, 1797. Vol. i. p. 152.

[2] Beiträge zur nähern Kenntniss des Galvanismus. Weimar, 1805. Vol. i. p. 28.

[3] Quæstiones physiologicæ de phænomenis galvano-magneticis in corpore humano observatis. Lipsiæ, 1836.

blistering the skin, and by applying warm instead of cold conductors.

Lenz and Ptschelnikoff[1] discovered that the conductivity of the body differs greatly according to the conducting liquid that is used. Thus if water from the river Neva was taken, the resistance amounted to 16°·53; on adding one part of sulphuric acid to a hundred parts of water, it fell to 6°·06. A scratch made on the hand further reduced it to 4°·81; and if four parts of sulphuric acid were added instead of one, the resistance was only 4°·37. They also found that young people do not conduct as well as the aged; that the callous extremities of working men have more resistance than the delicate skin of persons of rank; and that the resistance of the right hand is greater than that of the left.

The fact that young persons should conduct less well than elderly people, is, by Du Bois-Reymond, attributed to the smaller transverse section of their fingers, which, next to the epidermis, are the worst conductors. Ranke,[2] however, thinks it rather more dependent upon the different chemical composition of the liquids and tissues of youthful and elderly people. Infantile tissues contain a greater proportion of water, and adult or senile structures a more considerable quantity of salines, other things being equal; and this would sufficiently explain why the aged body conducts better than the youthful one. Probably the physical as well as the chemical differences contribute equally towards this result.

There are certain differences in the resistance of different persons, and of the same individuals at different times, which have not yet been satisfactorily explained. Some

[1] Ueber den Leitungswiderstand des menschlichen Körpers gegen galvanische Ströme; in Poggendorff's Annalen, vol. lvi. 1842, p. 429.

[2] Tetanus. Eine physiologische Studie. Leipzig, 1865, p. 13.

persons are naturally better conductors than others; and this is no doubt in some measure due to the great variety which exists in the quantity of perspiration in different individuals. But this alone is not sufficient to explain all the phenomena of this class which have been observed. Thus, when shocks from a Leyden jar are transmitted through a number of persons forming a chain, some people in the chain feel the shock very slightly, or not at all, and some arrest its propagation altogether; while others feel it most severely. Now, this might be explained if the hands of those who stop the shock were always dry, or their epidermis very thick; but persons have often stopped the propagation of the shock who have a delicate cuticle, and although this may have been purposely moistened in order to facilitate the transmission. Again, at other times, the same people may feel the shock distinctly. Similar observations have been made with regard to lightning. Thus, a single person has been struck in the middle of a group of men, and all others remained untouched; and again, a number of persons standing together have been killed by the stroke, while one of them escaped without injury. It is also understood that certain Indians and negroes can handle the electric eel without being affected by it; and Mr. Flagg asserts,[1] that if a number of persons join hands and one touch the eel, they are all equally shocked, unless there should happen to be one of the number incapable of being affected by the eel, which is (he says) 'the case of a very worthy lady of my acquaintance, who can handle this fish at will.'

The circumstances affecting the conductivity of the human body are exceedingly complicated, because the body is not a

[1] Transactions of the American Phil. Society, held at Philadelphia, 1786, vol. ii. No. 13.

homogeneous mass, such as a copper wire or a steel bar, but consists of a great variety of differently-conducting substances moulded into one, and all of which have a definite influence upon the electric resistance of the whole. Not only have we to consider nerves, muscles, bones, skin, blood, lymph, and other substances of widely different chemical composition, but all these organs and liquids again differ in conduction according to shape and bulk. The thickness of the skin in different parts of the body differs extremely; its degree of moisture varies not only according to locality, but also according to the temperature, and the more or less dry condition of the atmosphere; according to individuality, rest or exertion, present state of health, and a variety of other circumstances which act as disturbing influences. We shall, therefore, never succeed in determining the resistance of the human body with the same scientific exactness as that of the metals, which we can render chemically pure, reduce to any shape we like, and examine at any degree of temperature. Nevertheless, we know a number of facts which are of great practical importance, and by the aid of which we can render the influence of electricity upon the body tolerably precise.

If the human body be interposed into the galvanic circuit, the current will enter it and pass through it according to certain laws. The density of the electricity will be greatest at those points where it enters and leaves the body, and small at any intermediate portions of the same. An absolute localisation of electricity is therefore impossible, and if we speak of localised applications, this is only relatively true. It is easier to localise the induced than the continuous current, because the quantity of the latter is so large that it will spread to a considerable distance from the electrodes.

It appears from the researches of Magrini, Becquerel, and others, that the galvanic current is propagated by a wave-

like motion. It is true that the density of the current is greatest when it enters and leaves the body, and in a straight line between these two points; but the electricity is not confined to these ways, and spreads, although less energetically, throughout the neighbourhood. The different waves of the current unite, so to say, near the electrodes, which is the reason that there the most powerful effect is produced. Moreover, the size of the conductors which is used is of influence; the larger their diameter the greater is the quantity of electricity which is caused to pass through the body.

Conductivity of Tissues.—Researches on the resistance of the different animal tissues are of recent date. The old physiologists, who had not experimented on the subject, believed that the nerves were the best conductors of the body, carrying the orders of the will with lightning-like rapidity to the muscles. But the first experiments which were made on this matter by Heidmann, in 1805, and again those of Person,[1] in 1830, seemed to show that the nerves did not conduct much better than the muscles and other animal substances.

In 1843 this subject was taken up by Matteucci,[2] whose experiments led him to the conclusion that the muscles are the best conducting tissue in the body; that the brain, the spinal cord, and the nerves, are not very different from each other in this respect, and that they conduct four times worse than the muscles. In order to ascertain the relative resistance of nerves and muscles, he used a layer of the cerebral substance, a piece of the sciatic nerve, and a portion of a muscle from the thigh of a recently-killed rabbit; reduced these substances to slices of the same thickness, and caused

[1] Sur l'hypothèse des courans électriques dans les nerfs; in Magendie, Journal de la Physiologie expérimentale. Paris, 1830.

[2] Traité des phénomènes électro-physiologiques des animaux, etc. (Paris, 1844), p. 47; and Comptes-rendus (1843), p. 23.

a current of twelve pairs to pass through them whilst lying on an insulating plane. He then touched similar pieces of nerves and muscles with the extremities of a sensitive multiplier, which were held at equal distances from each other, and noticed that the needle was more strongly deflected on touching the muscle than on touching the nerve, the amount of deflection being inversely proportional to the resistance offered by these substances to the passage of the current. He afterwards altered the distance between the ends of the multiplier, so as to obtain equal deflections of the needle, whether the nerves or the muscles were touched ; the resistance being in this instance inversely proportional to the length of the animal substances comprised between the ends of the multiplier. He then found that, in order to obtain the same deflection of the needle, he had to approach the ends of the multiplier to one another when he touched the nerves ; whilst when he touched the muscles, he had to increase the distance between the ends of the multiplier. From this Matteucci calculated that the muscles conduct four times better than the nerves, which latter conduct rather better than the brain and the spinal cord.

The experiments of Matteucci were repeated, and on the whole, confirmed, by Dr. Schlesinger,[1] of Vienna, but are nevertheless in some respects objectionable.

Du Bois-Reymond has pointed out that the slices of the different tissues can never be exactly of the same length and diameter. Matteucci likewise neglected to measure the intensity of the battery current ; and finally it is inexplicable that he should have obtained exactly the same results by both proceedings he employed ; as in the former an influence

[1] Die Elektricität als Heilmittel. Zeitschrift Wiener Aerzte, July, 1852.

must have been exercised by polarisation, while there was no such influence in the latter.

Matteucci's results were to some extent upset by the experiments of Prof. Eckhard,[1] of Giessen, who found that the resistance offered by the muscles, tendons, nerves, cartilages, and bones, is not always the same, because the amount of water contained in these tissues is variable, not only in different individuals of the same species, but also in the same tissues taken from different parts of the same body. Thus the median nerve at the fore-arm contains fewer blood-vessels than the sciatic nerve where it emerges from the pelvis, and in accordance with this fact the median nerve is found to conduct less well than the sciatic. Finally, it should be considered that water evaporates all the time while the tissues are reduced to such a shape as to be fit for observation; and that differences are therefore inevitable, according to the temperature of, and the amount of moisture contained in, the atmosphere.

As animal tissues, with the exception of the nerves and the lumbrical muscles, cannot be well reduced to such a shape as to show perfectly identical longitudinal and transverse sections, which is a necessary condition for the exact calculation of their conductivity, Eckhard did not compare directly the resistance offered by the several tissues, but first determined that which is offered by some piece of animal tissue, from which he took a cast in plaster of Paris, and then formed a piece of glue perfectly similar to the piece of tissue which had been examined; finally, he measured the resistance of the piece of glue. The glue used for these experiments was always of the same strength and temperature. For ascertaining the conductivity of muscle, Eckhard used fibres taken from a dead body after rigor mortis had disappeared, because before that it is not possible to form a

[1] Beiträge zur Anatomie und Physiologie. Giessen, 1858. Vol. i. p. 57.

piece of glue perfectly like the piece of muscle. In order to avoid the shrinking which might be occasioned by the hygroscopic property of plaster of Paris, he covered the muscular fibres with a layer of fat before he took the cast. After having determined the comparative resistance offered by the different animal substances and glue, he calculated the relative differences in the conductivity of the animal tissues themselves.

Having put the resistance of fibres taken from the sartorius muscle of man = 1, Eckhard found the resistance of the tendon of the gastrocnemius = 1·7 to 1·9; of the tendon of the semitendinosus = 2·2 to 2·4; and of the tendon of the extensor carpi radialis = 2·3 to 2·6; therefore the average resistance offered by tendons would be 2·1. That of the cartilages of the ribs varied from 1·7 to 2·4; average 2. The resistance of nerve-fibres taken from the brachial plexus was 1·9 to 2·4; that of the sciatic nerve 2·2; average 2·1. The compact substance of the bones appeared to conduct 16 to 22 times worse than muscle.

The result of Prof. Eckhard's researches may therefore be summed up as follows:—

The resistance of muscles is	=	1.
,, of cartilages	=	2.
,, of tendons	=	2·1.
,, of nerves	=	2·1.
,, of bones	=	19.

These numbers correspond very nearly with the amount of water contained in the tissues; for if we take the average of reliable chemical analyses of animal substances, we find that—

The muscles contain	76	per cent.	of water.
The tendons ,,	62	,,	
The cartilages ,,	62·5	,,	
The nerves ,,	52·5	,,	
The bones ,,	5	,,	

The apparent divergencies in the numbers may be ac-

counted for by the circumstance that the conductivity of the tissues is not exclusively due to the amount of water, but also to the quantity of salines contained in them.

Although Eckhard's researches were carefully made, their results cannot be considered as final, because he did not experiment directly on the tissues themselves; because dead tissues must have a different conducting power from living ones; and because the influence of polarisation was not thoroughly avoided in his experiments.

Du Bois-Reymond[1] has considered the question whether the different conditions of living muscle have any influence upon its conductivity, and whether the negative variation of the muscular current discovered by him has anything to do with the differences in the resistance of muscular fibres which are observed when they are contracted and when quiescent. He found that during contraction the resistance was increased, owing to the alteration in the shape of the muscle; while, if this alteration was excluded, the contraction appeared to be accompanied with a slight diminution of resistance.

M. Ranke,[2] of Munich, has more recently investigated this subject. He used the adductor muscles of the frog's thigh, which, as they consist of longitudinal fibres, do not evolve a current of animal electricity in their natural longitudinal section. As, according to Du Bois-Reymond, alterations of shape have an influence on the resistance of the muscle, such alterations were, as far as possible, excluded by using a clamp, which may give to a muscle fixed in it any degree of tension which may be required. The difficulty which had always been experienced by previous observers, of giving to the animal tissues a stereometrically definite

[1] Untersuchungen über thierische Elektricität, vol. ii. p. 174. Berlin, 1854.

[2] Loc. cit. p. 27.

shape, Ranke endeavoured to overcome in the following manner:—The elasticity of the tissues allowed him to draw them into a fine glass tube, which was completely filled by them, the terminal surfaces of the preparation being made parallel with both openings of the tube. By this proceeding he could not only give a definite shape to any tissue, but also give the same shape to all sorts of different tissues, so as to avoid errors which might otherwise occur in measuring their dimensions.

According to Ranke, living muscle conducts 3,000,000 times worse than mercury, and about 115,000,000 times worse than copper. The resistance of dead muscle as compared with living muscle is as 56 to 100; it therefore conducts 1,680,000 times worse than mercury, and 64,400,000 times worse than copper. This diminution of resistance in dead muscle is owing to the accumulation of certain products of decomposition, the most important of which seems to be lactic acid; for, other circumstances being equal, an acid muscle naturally conducts better than one which is not acid. Boiling diminishes the resistance of the muscular fibre for the same reason, and contraction has the same influence.

Ranke's experiments appear to have considerably simplified the subject under consideration. We may now take it for granted, that *when the current has once overcome the resistance of the cuticle and the bones, it will spread almost equally through all the organs which are interposed between the two electrodes, the greatest effect being always produced near the electrodes.*

With regard to the conductivity of bones, the resistance of which was put down by Eckhard as varying from 16 to 22, direct observations have hitherto been wanting. Dr. Friedleben, of Frankfort,[1] has shown that almost all chemical

[1] Wunderlich's Archiv der Heilkunde (1861), p. 139.

analyses of bones which have as yet been made, concern only osseous tissue which has been carefully dried. Chemists as well as pathologists and histologists seem to have thought that the quantity of water in bones was something accidental and irrelevant. Their analyses therefore teach us nothing about the actual composition of osseous tissue in the living body. Nasse has incidentally mentioned that the average amount of water in the ribs is 42·8 per cent. Becquerel found in the skull-bones of a rickety child, who had died of pneumonia, 35·2 per cent of water. Stark[1] says that on the whole the bones of fishes contain most water, viz. from 50 to 80 per cent; that the bones of young birds contain more than that of old birds (from 12 to 25 per cent); that the flat bones of mammalia contain generally more water than the round bones of the extremities (the former from 12 to 20, the latter from 3 to 7 per cent); that the more spongy the substance of bones, the greater is the amount of water, and that the human bones contain more water than the bones of any other mammalia. All these assertions, however, are contradicted by Friedleben, who has shown that several sources of error are inherent to Stark's method of investigation. He justly contends that most bones which have hitherto been analysed were not fair specimens, as they were taken from persons who had by previous illness suffered from considerable disturbances of nutrition, and that consequently the chemical composition of the bones must have been altered likewise. This holds good especially for young people, in whom the composition of bones appears to be rapidly affected whenever the nutrition of the system generally suffers; in rickets, for instance, the amount of water in the bones is greatly increased. Further observations are therefore required to elucidate the conducting power of bones in the living subject.

[1] Edinburgh Med. and Surg. Journal, vol. lxiii. (1845) p. 308.

Resistance of the Nervous Centres.

a. The brain.—Many physiologists and physicians have denied the possibility of guiding a galvanic current of moderate power through the brain of the living man, thinking that its passage to that organ was prevented by the resistance of the soft parts and the bones of the skull. Prof. Erb,[1] of Heidelberg, however, has justly contended that the obstacles encountered by the galvanic current on its way to the brain are not so great as has been generally supposed. We have already seen that the conducting power of the bones is better than it was formerly believed to be. In fact, the epidermis is a worse conductor than the bones, because it does not contain so much water as they do. It only conducts at all in consequence of being perforated by numerous small canals, viz. the excretory ducts of the sudoriferous glands and the sebiparous follicles, which in their turn do not conduct as well as the blood-vessels which traverse the bones. Moreover, if the current be applied to the skull itself, it is only slightly diverted from its direction by better conducting soft parts; since the epidermis, the corium, the galea aponeurotica, the periosteum, and the bones form layers directly superposed upon one another, and cannot prevent a current of moderate power from entering the intracranial cavity.

The following experiment of Erb shows that a portion of the current follows the shortest road between the two electrodes:—The two forearms are crossed over, so that they touch one another about three inches above the wrist, their anterior surfaces having been previously well moistened. One electrode is then placed on the dorsal surface of the right, and the other on that of the left forearm, and a current of some intensity passed through the same. After

[1] Deutsches Archiv etc. 1867, vol. iii. p. 237.

some time, a sensation of heat is felt in the dorsal surfaces, and a similar, although more feeble, sensation on the volar surfaces. On removing the electrodes, not only that part of the skin which was in contact with them appears to be diffusely reddened, but a similar effect is shown to have been produced at the point where the volar surfaces touched each other, although the redness at these latter parts is not so uniform, and appears more in patches, corresponding to the sebaceous follicles. In this experiment there are two roads open to the current, viz. a longer one through the muscles of the arm and trunk, which offer less resistance; and a shorter one straight through the forearms themselves, where more resistance is offered by the epidermis. The result is, that the larger portion of the current travels by the long road, which has a better conducting power; while the smaller part of it takes the shortest way, as shown by the sensation of heat which is experienced, and the redness which is perceptible, at the end of the experiment. Now, as the resistance of the bones is known to be less than that of the epidermis, Erb concludes that a current which is applied to the two opposite surfaces of the skull must, if not wholly, at least partially, penetrate into the cranial cavity and act upon the cerebral matter.

The same observer has made experiments on dead subjects which plainly show that the galvanic current can be made to pass through the substance of the brain. He opened the skull, removed the brain, and covered the top of the skull with a layer of muscular substance, two inches wide and three-quarters of an inch thick, so that it went from the occipital spina to the glabella. Pieces of skin were interposed between the muscular flesh and the electrodes. The skull-cap was then filled with cerebral matter, but the contact of this with the muscular substance was carefully avoided. The edges of the skull having been well dried, a

prepared frog's limb, resting on the cerebral matter, was then interposed between the two electrodes, and a feeble current, which produced only slight pricking when applied to the face, sent through the tissues. It was then observed that, on closing and opening the circuit, the frog's limb contracted vigorously. Erb concludes from this that, although the electrodes were connected by well-conducting muscular tissue, a current of perceptible power entered the brain nevertheless. The induced current produced the same effect on the frog's limb as the continuous current.

The same observer made the following experiment:— A rectangular piece of bone was removed from the skull-cap, and the skin and periosteum dissected away from the edges of the bones, and retracted; part of the dura mater was removed, and the blood and cerebro-spinal fluid were allowed to escape. The edges of the bones were then carefully dried, and the body was left for three hours in a warm room, so as to remove all the moisture from the edges of the bones. A piece of brain-matter was then taken out, and the nerve of a frog's limb placed in the fossa thus formed, while the other parts of the frog's limb were insulated by a thick covering of dry paper. The electrodes were then applied above the ears, with the result that a current which could be easily borne on the face of the experimenter caused distinct contractions in the frog's limb; these latter became stronger, if one pole was put to one side of the forehead, and the other one to the mastoid process of the opposite side. The application of the induced current produced the same effect.

Erb has therefore shown that during the application to the head of a continuous and an induced current, which are so feeble as to be perfectly suitable for therapeutical application, portions of the current traverse the brain in such quantity and intensity as to have a decided effect upon a

frog's limb, although this may occupy only a small space in connection with the cerebral matter; and he argues that, in the living body, circumstances would be even more favourable for the transmission of the current to the brain, because there the temperature is higher, and circulation going on.

It might be objected to these conclusions that a current which will excite the nerve of a frog's limb is not sufficiently strong to produce an appreciable therapeutical effect on the brain. But if we consider that the frog's nerve touches only a very small portion of cerebral matter, and that, in all probability, the current, when applied to the head, traverses all portions of the brain equally, this current cannot be excessively feeble. Moreover, it has not been shown that a current must be very powerful in order to be useful. On the contrary, we shall see in the third chapter that a gentle current, which can be easily borne even by sensitive persons, produces the greatest therapeutical results, and that a powerful current only does harm instead of good.

b. The spinal cord.—Whether any form of electricity, applied in moderate power to the spine of the living man, is transmitted to the cord itself, has, until quite lately, been a matter of controversy. Judging from therapeutical effects, I am inclined to believe that static electricity, electro-magnetism, and magneto-electricity only act on the nerves of the skin of the back, and not on the substance of the cord, but that the continuous current has a decided action on the latter. Erb[1] thinks that the bones of the vertebral column offer less resistance to the passage of the current than the skull. They are more spongy, contain more water, and the several bones are separated from one another by large and numerous lacunæ, fitted up with blood-vessels, nerves, and connective tissue,

[1] Loc. cit. p. 435.

along which the current may easily penetrate into the spinal canal. There is, however, this difficulty, that we can only apply the current to one surface of the cord, and that it cannot be sent right through it, as it may be through the head; but, on the other hand, a much more powerful current may be safely applied to the cord than to the brain, whereby some compensation is afforded for the disadvantageous anatomical position of the cord.

Erb performed the following experiment on a dead subject, with the view to elucidate these conditions:—He removed the bodies of the seventh cervical vertebra and of the first three dorsal vertebræ, and the dura mater, so as to lay the cord open, the parts being carefully dried. The nerve of an isolated frog's limb was then placed on the cord, and the anode of a constant battery directed to the mastoid process, while the cathode was applied to the sixth dorsal vertebra. Contractions took place in the frog's leg on opening as well as on closing the circuit, showing that the current actually passed through the cord.

Experiments on the living man have shown that it is possible, by applying the two electrodes of a somewhat powerful constant battery to the spine, to produce contractions of muscles, which are animated by nerves situated far below the points where the electrodes are applied. Thus, for instance, if one large electrode was placed near the first dorsal vertebra, and the other to the spinous process of the second and third lumbar vertebræ, and a current of some power was sent through, contractions were caused not only in the muscles of the back, but also in the hamstring muscles of the thigh, which are animated by the sciatic nerve; care being taken that the direction of the current was occasionally rapidly changed in the metallic circuit. By this latter proceeding *voltaic alternatives* are produced which considerably increase the excitability of the nerves;

and, after several such alternatives had taken place, contractions of the same muscles could be caused by simply interrupting the current. This shows that the sciatic nerve must have been electrically acted upon within the spinal canal, and that a continuous current, sufficiently powerful to produce decided physiological effects, may be sent through the cord of the living man.

Erb's experiments have been corroborated by Burckhardt,[1] who has investigated the resistance not only of the brain and cord, but also of the cervical sympathetic and the nerve-trunks of the upper and lower extremity. The current that was to act upon the brain, was applied either through the temples, or from the forehead to the occiput; that which was to affect the cord, was applied to the upper and lower end of the spine; and that which was to travel through the cervical sympathetic, was directed to the angle of the lower jaw and the manubrium sterni. Every one of these experiments gave positive results, inasmuch as it appeared that the brain, cord, cervical sympathetic and peripheral nerves, were traversed by portions of the current, which, when derived from these organs by means of steel needles, caused considerable deflections of the needle of the galvanometer. The direction of the current traversing these organs corresponded with that of the principal current; and if that of the latter was reversed, the magnetic needle at once gave an opposite deflection.

In one of his experiments Burckhardt imitated the vital conditions so as to produce a kind of artificial circulation. Rhythmical injections of salt water were made into the aorta of a subject, with the result that the upper portion of the body became warm, the veins of the arm distended, the cadaveric rigidity diminished, and warm water was seen to

[1] Deutsches Archiv für klinische Medicin, 1870, vol. viii. p. 100.

flow from incisions into the limb. Under these circumstances the current derived from the organs appeared much stronger than where a dead subject in its ordinary condition was acted upon; from which Burckhardt justly concludes that *the current will traverse the organs more easily during life than after death.*

Ziemssen,[1] who was formerly the leader of that party of electro-therapeutists which denied the possibility of affecting the centres of the nervous system by the galvanic current, has recently been altogether converted to the other side, and has added some valuable experimental proofs to those already furnished by Erb and Burckhardt. He experimented on dead subjects, and recently-killed animals, and found that a plainly perceptible portion of a gentle current, such as is now generally employed in therapeutics, may be derived from the organs; that this derived current has a definite direction, and that its intensity may be increased by increasing the intensity of the principal current.

The brain, freshly removed from the skull, conducts extremely well; and the current which may be derived from it is most intense when the deriving needles are in a straight line between the two electrodes. Thus, if the current was sent longitudinally through one hemisphere, and the deriving needles were placed straight between the principal electrodes, the deflections were as follows:—

6°·8	with 1	pair of Siemens's (Daniell-Muirhead's)	battery.	
11°·2	„ 2	pairs	„	„
21°·7	„ 3	„	„	„
32°·6	„ 4	„	„	„
43°·8	„ 5	„	„	„

On the other hand, if the deriving needles were placed laterally from the principal electrodes, the deflection was considerably diminished. It was only—

[1] Die Electricität in der Medicin. Vierte Auflage. Berlin, 1872, p. 30.

4°·9 with 1 pair of the same battery.
7°·9 „ 2 pairs „
15°·2 „ 3 „ „
22°·8 „ 4 „ „
31°·5 „ 5 „ „

Conducting Power of the Eyes.

It likewise appears from Ziemssen's researches that the eyes possess an unusually high conductivity. Thus, for instance, if the electrodes of the principal current were placed on the temples, and the deriving needles introduced into the eyes, the following deflections were obtained:—

With 1	Siemens's	pair	6°·4
2	„	pairs	7°·3
3	„	„	8°·5
4	„	„	9°·1
5	„	„	10°·0
6	„	„	11°·2
7	„	„	13°·7
8	„	„	17°·5
9	„	„	24°
10	„	„	34°·4

Ziemssen has calculated the resistance of

the brain	at	1,693·3	Siemens's units.
the eyes	at	2,651·2	„
the muscles	at	6,192	„
the liver	at	11,592	„

The eyes, therefore, conduct nearly three times better than the muscles, and are, as far as conducting power is concerned, only surpassed by the brain. Since, however, the brain is much more thoroughly protected by its membranous and osseous coverings than the eyes, which latter, by means of the highly vascular connective tissue that surrounds them, are in an intimately conducting connection with the cheek, the eyes might almost be pronounced the best conducting part of the body. This is in accordance

with the quantity of water contained in them, which, according to Gorup-Besanez, is 90 per cent.

Ziemssen obtained positive results with the organ of hearing, the tongue, the cervical sympathetic, the lungs, heart, liver, spleen, intestines, and bladder. The deflections were always greatest if the deriving needles were in a straight line with the electrodes of the principal current.

Another important fact which has resulted from the observations of Burckhardt, Brückner, and Ziemssen, is that the deflection increases with the distance of the deriving electrodes from one another. Thus, for instance, if the sartorius muscle was insulated, and the deriving electrodes were placed at different distances, the following deflections were obtained:—

a.	1 centimètre distance,		5 Siemens's pairs		.	.	1°·2
	10	„	„	„	„ .	.	6°·1
	15	„	„	„	„ .	.	24°·2
b.	1	„	„	10	„ .	.	4°·2
	10	„	„	„	„ .	.	15°
	15	„	„	„	„ .	.	74°·6

It is probable that the conductivity of tissues is *changed during disease*, but accurate observations on the subject are as yet wanting. Dr. Sycyanko,[1] of Cracow, has noticed diminished conductive power in diseased joints. A current from a battery of twenty zinc and carbon plates passing through a healthy leg, gave, with Siemens's multiplier, a deviation of 15° or 20°, while thirty pairs of plates in a diseased knee gave a scarcely appreciable deflection.

Anchylosed joints commonly offer an increased resistance to the galvanic current, in proportion to the stiffness of the joint. This is easily explained by the circumstance that such joints contain an increased quantity of solid matter, and less water than healthy joints. On the other hand, we might expect that in conditions where the reverse takes place, viz. an increase

[1] Medical Times and Gazette, April 3, 1869.

of water at the expense of solid tissues, the conductivity of pathologically-altered structures would appear increased.

(B) ELECTRO-MAGNETISM (*syn. Faradism, Volta-Faradism*[1]).—Phenomena showing the close relation that exists between electricity and magnetism, have been observed centuries ago. By a lightning-stroke masses of steel and iron have been magnetised; watches have been stopped in consequence of the magnetisation produced by lightning in the pieces of steel of the balance; the poles of mariners' compasses have been reversed by the fall of lightning upon ships—an occurrence which has, in some instances, been attended with fatal results to sailors, who being guided in a contrary direction, were cast upon rocks, from which they thought they were receding at full sail.

In 1819, Oersted, a Danish philosopher, made the first scientific observation on the action of electricity upon a magnet. He found that when the two poles of a galvanic battery are united by a metal wire, placed closely above or below a magnetised needle, the needle suffers a deflection, the extent of which is directly proportional to the power of the battery, and inversely proportional to the distance between the needle and wire. The needle tends to place itself at a right angle to the conjunctive wire, and succeeds in attaining this position when the current of the battery is powerful and the needle very near to the wire.

Astatic Needle.—Ampère then drew the attention of natural philosophers to the fact that the magnetism of the earth prevents the magnetised needle from entirely obeying the action of the current, as that influence continually tends to reduce the needle to the plane of the magnetic meridian.

[1] The term 'Faradism' has been proposed by M. Duchenne (de Boulogne), who has also coined the words 'faradise' and 'faradisation.' 'Volta-faradism' means electro-magnetism, as distinguished from 'magneto-faradism' or magneto-electricity.

To obviate this inconvenience he constructed the so-called *astatic needle*, composed of two magnetised needles placed in a parallel direction, whereby the influence of the earth is more or less counter-balanced. But the two needles cannot, under any circumstances, be perfectly alike, nor placed in two directions exactly parallel, nor possess absolutely the same quantity of magnetism; and therefore the earth will always exercise a certain amount of action upon the astatic system. The effect of an electric current is, however, much stronger upon a double than upon a single needle; and a very feeble current which is not able to deflect the latter, will produce a marked effect upon the astatic system, especially if the wire by which the current is transmitted be bent, so that it is no longer above or below the needle, but forms two parallel branches, between which the needle is suspended; care being taken that the current does not pass directly from one coil to the other, which is prevented by covering the wire with an insulating sheath of silk or gutta percha. If there be two such coils, the action of the current upon the needle is twice as powerful as if the wire had been only above or below the needle, and each further convolution of the wire will proportionately increase the action of the current upon the needle.

Soon after Oersted's discovery had been made known, Arago found that the electric current imparted a strong magnetic force to pieces of soft iron, steel, and other magnetic bodies, which did not possess it previously. He saw that when a fine iron wire was traversed by the current, it acquired the property of attracting iron filings, which dropped again when the current ceased to pass. Arago succeeded likewise in magnetising needles by discharges from a Leyden jar. He showed that, if a copper wire covered with silk or gutta percha be coiled round a bar of soft iron, and an electric current be made to pass through the wire, the soft iron,

although it does not form part of the circuit, yet becomes powerfully excited by the surrounding wire. Each convolution of the wire causes a certain amount of magnetism in the iron; and by employing a large number of convolutions, a magnet of enormous power may be produced. This magnetism is, however, not permanent, for it ceases at once when the circuit is broken. Within an instant the electric current may magnetise the iron by its passage, and demagnetise it by its cessation. Such temporary magnets are termed *electro-magnets*, in order to distinguish them from permanent magnets of steel.

Induction Currents.—Science had advanced thus far when Faraday discovered, in 1831, that a galvanic current is able by induction to develope electric currents in conducting wires. This is proved by the following experiments:—Two conducting wires are placed on an insulating plane, parallel with, and very near to, each other; the two ends of the first wire are then connected with the poles of a galvanic battery, and the two ends of the second wire with the extremities of a multiplier, in order to enable us to ascertain the electric movement in the wire by the deflection of the needle. At the moment when the battery current is made to pass through the first wire, the needle of the multiplier communicating with the second wire is deflected, then suffers some oscillations, and finally returns to rest, which remains undisturbed as long as the battery current continues to pass through the wire. But as soon as the communication between the battery and the first wire is interrupted, the needle suffers another deflection in a contrary direction to that in which the former had occurred. From this it appears that the galvanic current which traverses the first wire determines in the second an instantaneous current at the moment when it begins to circulate, and another equally instantaneous current at the moment when it ceases to pass.

The multiplier indicates not only the existence of such instantaneous currents, but also their direction; showing that the current induced in the second wire on *making* the circuit flows in a direction *contrary* to that of the battery current, while the direction of the current induced in the second wire on *breaking* the circuit is *equal* to that of the battery current. The intensity of these instantaneous currents may be increased by employing two copper wires of great length covered with silk or gutta percha, and coiled round a hollow reel, so as to form two helices, the convolutions being as near as possible to each other.

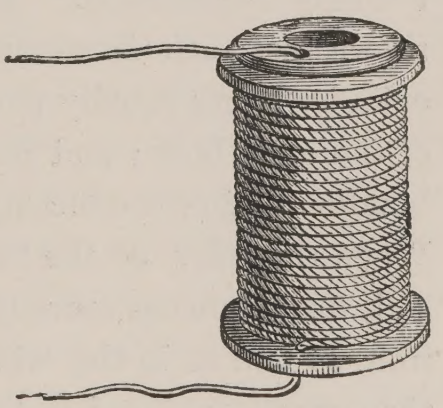

Fig. 36.—Induction Coil.

The intensity of induction currents is further increased by introducing into the cavity of the coil pieces of soft iron, which become magnetic under the influence of the battery current, and thereby produce other electric currents in the two wires. The centre-piece of soft iron is generally called the *core*; and it is not necessary that it should be very close to the convolutions of the coil. How the influence is transmitted from one to the other, is a most perplexing question, which yet awaits its solution. The currents produced by the magnetism of the soft iron are equally instantaneous as the currents developed by the inducing current of the battery. They are not produced whilst the soft iron is magnetic, but only at the moment when it acquires and loses its magnetism. Therefore the demagnetisation of the soft iron has the same effect as breaking the current of the battery, in the production of an instantaneous induced current.

The power of the electro-magnet to increase the intensity of induction currents differs according to the shape and quantity of the iron. It is sufficient for producing a striking effect, to have a single piece, or a hollow cylinder, of soft iron round which the copper wires are coiled, but the effect is increased if a bundle of iron wires be used; and yet more, if these wires are insulated from each other by layers of varnish. It was formerly believed that the increased effect was due to the circumstance that the iron wires are softer than a solid cylinder, and therefore would become more strongly magnetised. But Prof. Magnus, of Berlin, has shown that such is not the case, the magnetism of a solid cylinder being equally powerful as that of a bundle of wires of the same bulk; and that the increased effect is due to the bundle of wires conducting less well than the solid cylinder. When the poles of the battery are in connection with the coil, instantaneous currents are produced in the central soft iron, as well as in the wires that are coiled round it. Now the current produced in the soft iron on breaking the circuit notably retards the demagnetisation of the soft iron; its magnetism, therefore, disappears much more rapidly if the production of currents in it be prevented as much as possible. Electric currents are most easily produced in a solid bar of soft iron, less easily in a bundle of iron wires, and least so if these wires be insulated by varnish.

Prof. Dove, of Berlin, has shown that the intensity of an induced current is much diminished by covering the electro-magnet with a closed tube of a non-magnetic metal (brass or copper). This is due to the development of induced currents in the tube, whereby the magnetism of the soft iron is counterbalanced. The tube does not prevent the action of the current upon the galvanometer, but it greatly diminishes the magnetising as well as the physiological effects of the same. A metal tube covering the electro-magnet may there-

fore be employed as a regulator of the intensity of the current in physiology and therapeutics.

The first wire of the induction coil, the ends of which are connected with the poles of the battery, is comparatively short and thick, as the inducing current of the battery, which is propagated in it, is generally that of a single pair, and the resistance of the conducting wire must be slight, if a powerful electro-magnet is to be produced. But in the short and thick wire we have not only the battery current, but another one which is much stronger, and which is developed by the mutual action of the convolutions of the short and thick wire upon each other—an effect which only takes place if these convolutions are very near to each other; they therefore serve at the same time as inducing body and as induced body. This second current, which Faraday has termed *extra-current*, is produced not only when the circuit is broken, but also when it is established. Its direction is contrary to that of the battery current on closing, and equal to it on opening the circuit. Its energy is notably increased by the presence of soft iron in the interior of the bobbin; it is capable of deflecting the needle of a galvanometer, produces sparks, shocks, and heat, and decomposes water. The extra-current is due to induction by its own convolutions and by the electro-magnet; while the current induced in the second wire arises from induction by the battery current and by the electro-magnet.

Mr. Henry, of Princetown, has found that the action of induction is not confined to two coils; but that a current induced in the second wire may again induce another current in a third coil, if this be placed near the second; that the current produced in the third wire may give rise to a current in a fourth coil, &c. Mr. Henry has also determined the direction of these induced currents of the second, third, and fourth order, and found that if the current induced in the

second coil, *a b*, be positive, that induced in the third wire, *c d*, is again positive, whilst that induced in the fourth, *e f*, is negative, that in the fifth positive again, &c.

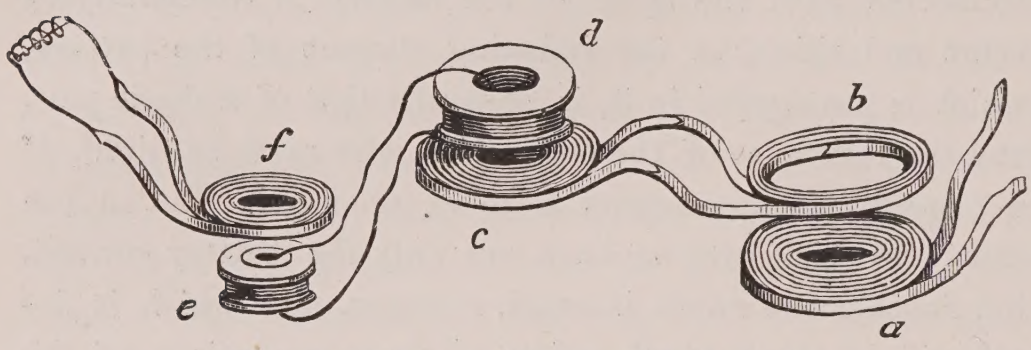

FIG. 37.—Induction Currents of Higher Orders.

The intensity of induced currents depends, in the first place, upon the intensity of the inducing current of the battery; if this be feeble, it will not be able to develope a powerful magnetism in the soft iron, and the extra-current, as well as the current induced in the second wire, will be of low tension. It depends, moreover, upon the transverse section, and the number of convolutions of the wires, being directly proportional to the number of convolutions and inversely proportional to the diameter of the wire, so that the current becomes stronger in proportion to the length and fineness of the wire. Finally, it depends upon the quantity, and the more or less insulated state, of the soft iron in the centre of the coil.

An induced current differs from a continuous current, in the first place, by its being instantaneous. To this circumstance is due the striking physiological effect of the former upon the motor nerves and muscles; for motor nerves and muscles are not excited by a closed circuit, but by variations in the density of the current. Again, the induced differs from the continuous current in so far as the direction of the latter is always the same, whilst the former moves alternately in different directions; for the deflections of the magnetised needle show that the current induced in the second wire, on

closing the circuit of the battery, has a direction contrary to that of the current induced on *opening* it. This circumstance gives rise to a peculiarity in the chemical action of the induced current. When water is decomposed by a continuous current, hydrogen appears at the negative, and oxygen at the positive pole. But such is not the case if induction currents are made to act upon water; for, as each wire alternately serves as positive and negative pole, both hydrogen and oxygen appear successively at either of the poles. The gases, therefore, represent an explosive mixture; and if the currents succeed each other rapidly, both gases appearing simultaneously, and both being in the nascent state, they combine again to form water, so that water is apparently unaffected by it. When platinum plates are used as electrodes and induction currents sent through them in rapid succession, oxygen is set free and oxidates the platinum; but oxide of platinum is immediately afterwards reduced to metallic platinum by the nascent hydrogen. Thus, a series of oxidations and reductions takes place, in consequence of which the platinum plates become at last covered with a black powder, which is finely-divided metallic platinum. Another experiment, showing that induction currents move alternately in different directions, is, to bring a solution of iodide of potassium and starch into the circuit; the blue colour indicating the liberation of iodine will then shortly appear at either of tho poles, while if we decompose that solution by the continuous current, the blue colour is only noticed at the positive pole.

It would, therefore, appear erroneous to speak of a permanent positive and negative pole in an induction apparatus employed for physiological or therapeutical purposes. Such is, indeed, the opinion of M. de la Rive,[1] who explains

[1] A Treatise on Electricity, in Theory and Practice. Translated by Charles Walker. London, 1858. Vol. iii. p. 603.

the difference in the physiological and therapeutical action of the extra-current, and of the current induced in the second wire, partially by the circumstance that the extra-current always moves in the same direction, whilst the current induced in the second wire alternately moves in contrary directions. But this author has evidently disregarded the fact, that the current induced in the second wire has scarcely any effect at all on *closing* the circuit, while it has a powerful physiological action on *opening* the circuit. We may, therefore, when employing induction currents in physiology and therapeutics, only consider the current induced on opening the circuit, which has a direction equal to that of the battery current.

We now proceed to take a short glance at Faraday's discovery of electric currents induced by a permanent magnet of steel.

(C) Magneto-Electricity (*Magneto-Faradism*).—If the pole of an ordinary magnet be approached to one end of a copper wire covered with silk or gutta percha, and coiled round a wooden reel, the needle of a galvanometer, communicating with the end of this wire, is seen to suffer a deflection. As long as the magnet remains in the same position, the needle is not further disturbed; but when the magnet is withdrawn, another deflection of the needle takes place, which indicates the existence of another instantaneous current produced in the wire, and moving in a direction contrary to the first. The current produced by a permanent magnet of steel is called the *magneto-electric* or magneto-faradic current, in order to distinguish it from the *electro-magnetic* or volta-faradic current induced by voltaic electricity. For producing a succession of magneto-faradic currents, the magnet must be continually approached to, and withdrawn from, the coil of wires. In order to effect a very rapid succession, therefore, the permanent magnet is not

made to act immediately on the wires, but an armature of soft iron, having the form of a horse-shoe, is surrounded by them, and set in rotation before the two poles of the magnet, by means of a wheel connected with an endless cord. By each turn of the wheel the two branches of the armature are made to pass before the poles of the magnet; at each passage there is magnetisation and demagnetisation of the soft iron; and an electric current is produced at the moment when the armature is approached to, and when it is withdrawn from, the magnet.

The intensity of the magneto-faradic current depends upon the power of the magnet, the number of convolutions and the diameter of the wire coiled round the armature of soft iron, on the distance of the armature from the poles of the magnet, and finally on the velocity with which the wheel is turned. The physiological effect is produced on making as well as on breaking the circuit; in the latter case the effect is stronger, but the difference is not so great as with the volta-faradic current. If it be, therefore, intended to avoid the continuous change in the direction, and to operate with a succession of currents all guided in the same direction, a wheel is employed, the teeth of which are alternately of metal and ivory, so that only one of the two currents which are produced is collected. But this can only be effected at very high speed, and the commutators generally soon get out of order.

M. Gramme has recently constructed a magneto-electric machine which promises to become of considerable practical value, and which has this peculiarity, that the current furnished by it is not intermittent, but continuous even at low speed. The machine is composed of three rings of soft iron encircled with an endless coil of copper wire. Each of these rings is made to rotate between the two poles of a powerful electro-magnet. The magnets are vertical cylinders

of soft iron, 3 feet 6 inches high, by $3\frac{1}{2}$ inches in diameter, and are coiled round with insulated copper wire. They are connected at the top by a square cast-iron plate, and at the bottom let into a base-plate 2 feet 8 inches square. When the machine is in action, the half of each ring which is next to the north pole of the magnet takes south polarity, while the opposite half, near to the south pole, takes north polarity. The two neutral points of the system are equi-distant on each side. The rings or bobbins are rotated on a horizontal axis, and when they are set in motion their polarity remains unchanged in position with regard to the operator. The action is therefore equivalent to the coils alone being rotated over a stationary ring-shaped magnet. The effect of this is to produce currents in the two halves of each ring in opposite directions between its two neutral points. At these points, however, contacts are placed, which touch in succession a series of studs insulated from each other and connected at regular intervals with the coil of wire. Thus the opposite currents in the two halves of each ring, instead of neutralising each other, unite and form a single current.

The machine can be turned by hand. The current appears to be producible in large quantities, at a much cheaper rate than by, and of equal constancy with, galvanic batteries. A further superiority of it over the batteries is believed to be found in the fact that the resistance remains the same, whatever may be the speed at which the machine is driven. Therefore, by driving it at double speed, twice as much electro-motive force is obtained, which represents twice as much current. It renders ten feet of platinum wire red-hot in a few seconds. The light which may be obtained with it is very brilliant and steady, and metals may be fused by it with great ease. It has also electrolytic effects, and is used by the firm of Christofle and Co., of Paris, for electro-plating.

Mr. Sabine has made some experiments in order to deter-

mine the electro-motive force of Gramme's apparatus, and has found that with a machine which contained four horse-shoe magnets 18 inches in length, 2 inches wide, and $\frac{3}{8}$ inch thick, and a coil composed of thirty-six bobbins, each containing 110 yards of copper wire, the following results were obtained :—

Handle turned, times per minute	Electro-motive force (Daniell's battery = 1)
60	16
100	28
120	33
180	47

With another machine which contains six magnets, and in which each bobbin contains 180 yards of wire, the results were similar :—

Handle turned, times per minute	Electro-motive force (Daniell's battery = 1)
60	16
120	32
180	47

In these experiments the handle of the machine was turned by hand, without much force.

In its present shape, Gramme's machine is not fit for medical practice ; but there can be little doubt that it will soon be utilised for it, and that magneto-electricity will thus once more become of therapeutical importance.

III.—ANIMAL ELECTRICITY.

Life is not possible without a continuous disturbance occurring in the equilibrium of the molecules of the body ; and as every disturbance of molecules is accompanied with a liberation of electricity, the existence of electric currents in the animal body during life appears a necessity.

That certain fishes, when touched, give shocks, was already known to the Romans, who employed them for the cure of headaches and gout. The best known among these fishes

are the *Torpedo*, or *electric ray*; the *Gymnotus*, or *electric eel*; and the *Malapterurus*, or *electric shad*. The Torpedo is frequent in the Mediterranean, and has been examined by Dr. John Davy,[1] Matteucci,[2] Kölliker,[3] and Max Schultze;[4] the Gymnotus is found in Surinam, in the ponds of Bera and Rastro, and has become known chiefly by the graphic descriptions of Baron Humboldt,[5] and the able researches of Professor Faraday;[6] while the structure and properties of the Melapterurus, which is found in the Nile, have been investigated by Bilharz[7] and Max Schultze.[8]

If an electric fish be touched at any part of its body, especially at the fins, it gives a violent shock, analogous to that yielded by the Leyden jar. In order to experience the shock, we may touch the fish either with the hand or with a good conductor of electricity, such as a metal rod. The discharges are also diffused to a considerable distance in the liquid in which the fish is contained; but if it be touched with glass or resin, no shock is perceived.

The electricity produced by these animals possesses all the properties of artificial electricity. It exercises attractive and repulsive powers; the sparks are sufficient to melt the leaflets of the electroscope; steel needles and soft iron may be magnetised; water, nitrate of silver, iodide of potassium, may be decomposed by it; and the needle of a galvanometer, when brought into the circuit, suffers a deflection, by which we are enabled to determine the direction of the current.

[1] Philos. Trans. 1832, vol. ii. p. 276; and Researches, Physiological and Anatomical. London, 1839.

[2] Essai sur les phénomènes électriques des animaux. Paris, 1840.

[3] Verhandlungen der Würzburger physikalisch-medicinischen Gesellschaft, vol. viii. p. 8.

[4] Zur Kenntniss des elektrischen Organs der Fische. Leipzig, 1859.

[5] Tableau physique des régions équatoriales. Paris, 1807.

[6] Experimental Researches in Electricity, Philos. Trans. 1844, vol. ii. p. 6.

[7] Ueber das elektrische Organ des Zitterwelses. Leipzig, 1857.

[8] Loc. cit. p. 45.

The quantity of electricity liberated in these fishes is in direct proportion to the energy of their circulation and respiration. After they have given numerous and powerful shocks, they require rest and nourishment, in order to store up a new amount of galvanic force.

The discharges are voluntary and entirely under the

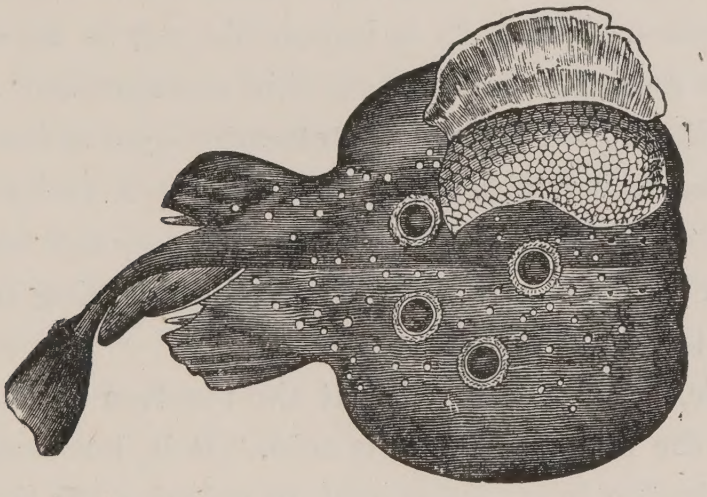

FIG. 38.—Torpedo, or Electric Ray.

control of the animals, just as the squirting of sepia from the cuttle-fish; and they are given in any direction they may desire. If metals be placed in the vessel containing them, the fishes become very much excited, and attempt to bite them.

It seems singular that the fish should not be injured by its own shocks. According to Du Bois' observations, the Malapterurus even possesses a certain immunity against foreign electricity; nevertheless, the fish seems to resent strong shocks which are applied to it, and, in order to avoid them as much as possible, places itself at the greatest distance attainable from the electrodes, at a point where the density of the current is least considerable, giving at the same time shocks of its own in self-defence.

Torpedo.—The electric ray, which is generally of incon-

siderable size, possesses a peculiar organ, by which the electricity is produced. This consists of small membranous prisms, *a b*, packed one against the other, like the cells of a honeycomb. These prisms are divided by horizontal diaphragms into small cells, which are filled with an albuminous fluid. It is impossible not to be struck by the close resemblance between this arrangement and that of the voltaic pile; indeed, the electric organ of the Torpedo constitutes a veritable battery, forming a series of solid diaphragms, positive on one of their surfaces and negative on the other; a conducting electrolytic liquid being interposed between the diaphragms.

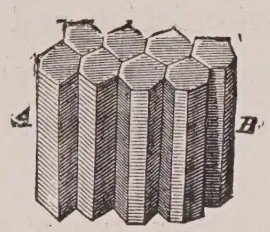

FIG. 39.—Electric Organ of the Torpedo.

Max Schultze discovered that the reaction of the electric organ of the living Torpedo is acid. It is, however, not yet known whether it is always acid, or only so after the fish has become exhausted by violent discharges of electricity.

The cells of the electric organ are traversed by numerous nerve-fibres, arising from four large nerve-trunks, which take their origin from the fourth lobe of the brain, in which the electric power resides. When this lobe is irritated, powerful discharges follow, even if the animal be to all appearance dead; that is to say, if by cutting, pinching, or squeezing it, no more shocks or movements can be produced. When the lobe has been destroyed, the discharges cease soon afterwards; they cease likewise when the connection between the brain and the organ has been interrupted by division or ligature of the nerves, although upon irritating the delicate nerve-fibres animating the organ, electric effects may still be obtained some time after that connection has been destroyed. The terminal branches of the nerves are very pale and slender; they anastomose in all directions, and form a delicate network, which is destroyed by most chemi-

cal tests which are employed in microscopical observations. The richness and density of this network has an important relation to the function of the electric organ. The electric action disappears forthwith when the albumen contained in the cells of the organ is artificially coagulated by boiling or by the application of acids, but as long as the albumen remains fluid, the discharges may continue even if the organ be lacerated.

When the Torpedo is fresh, shocks are felt wherever the animal is touched; but when it has become weary, and prepared frog's limbs are then placed upon different points of its body, it is easy to perceive that only those limbs suffer commotions which are in contact with the portion of the skin corresponding to the electric organ. The direction of the current is from the back to the belly of the animal; the upper surfaces of the prisms being all charged with positive electricity, the lower ones with negative electricity.

The shocks are given by the fish voluntarily, in order to kill animals necessary for its nourishment, or they are due to reflex action, just as in other animals muscular contractions are produced either voluntarily or by reflex action. If the fish be touched at any point of the skin, the stimulus is transferred from the cutaneous nerves to the brain, and from the fourth cerebral lobe back to the electric organ, by way of the four nerve-trunks connecting the lobe with the electric organ.

M. Robin has discovered that, when the fish is placed fully under the influence of ether, or is poisoned by woorara or strychnia, the shocks cease altogether. When the electric organ is at rest, it does not seem to possess any electromotive properties, nor does it seem to acquire them when traversed by a continuous galvanic current.[1]

Gymnotus.—The shocks given by the Gymnotus, or

[1] Eckhard, Beträge, etc., vol. ii. p. 157.

Surinam eel, which is from five to six feet long, are more powerful than the discharges of the Torpedo. Humboldt relates that this fish may kill at a blow horses and mules, and that some time ago it became necessary to change the road from Uritucu through the Steppe, because the electric eels had accumulated in a rivulet in such large quantities, that year after year a great number of horses were benumbed by the shocks and drowned in the passage. If the discharge takes place through a chain of persons, all of them feel a violent concussion.

The Gymnotus possesses an electric organ like the Torpedo, composed of a great number of prisms similar to voltaic piles. But while in the Torpedo the direction of the current is from the back to the belly, it is in the Surinam eel from the head to the tail; positive electricity being accumulated on the anterior part, and negative electricity on the posterior part of the body. If the animal be touched at the head and the middle of the body, or at the tail and the middle of the body, the shock has only half the intensity of that experienced when head and tail are touched at the same time.

In the Torpedo there are 940 series of diaphragms, each separate series containing 2,000 diaphragms; in the Gymnotus there are only 96 series of diaphragms, each containing 4,000 diaphragms. We have, therefore, 1,880,000 diaphragms in the Torpedo, and only 384,000 in the Gymnotus. Nevertheless, the shocks given by the latter are much more powerful than the discharges of the former; which is due to the larger surface presented by the diaphragms of the electric organ of the latter. Its electric power resides likewise in the brain.

Malapterurus.—The electric organ of the Malapterurus forms a tube surrounding the fish in its entire length, from head to tail. It is intimately united with the skin of the animal, and divided into two symmetrical lateral halves, by

a dorsal and ventral longitudinal septum. Numerous tendinous lamellæ traverse the organ, and form a sort of net-work, in the bi-pyramidal alveoli of which the electric plates are found, which consist of membranous expansions of the electric nerves. The net-work just described forms a support for the plates, the intermediate spaces between the tendinous and nervous membranes being filled with a viscid substance, which is probably albuminous. Bilharz has discovered that the electric organ of the shad is animated by a single primitive nerve-fibre emanating from each side of the spinal cord, at a point intermediate between the second and third spinal-nerve roots, and originating in a single nerve-cell of comparatively colossal size, it being visible to the naked eye as a small yellow point in the interior of the cord. The electric nerve, however, does not, as Schultze found, end in the corresponding half of the electric organ, but passes through an opening in the same, and turns backwards, spreading in the opposite surface. The current of the Malapterurus moves, in the organ and the water surrounding it, in a direction from the head to the tail, and in the wire of the galvanometer from the tail to the head.

The difference in the arrangement of the electric organs in the Torpedo on the one hand, and the Gymnotus and Malapterurus on the other hand, is to some extent explained by the fact of their living in media of different conductivity. The Torpedo lives in salt water, which is a comparatively good conductor, and has therefore a short and thick electric organ, while the Gymnotus and Malapterurus, which live in fresh water—that is, in a comparatively badly-conducting medium—have long, but thin organs.

Nervous and Muscular Electricity.—The electric currents circulating in other animals are not so easily perceived as those produced by the electric fishes; but there exists, nevertheless, a vast multitude of well-determined currents,

both in the nerves and in the muscles of all living animals, which have for the most part only local circuits; and the presence of these currents is not due to any physical or chemical action, but is subordinate to the life of the animal, since they disappear soon after death.

It is very difficult to make conclusive experiments of this kind, because the currents which we may collect are merely derived currents, the intensity of which is infinitely more feeble than that of the principal nervous or muscular current: in fact, the electro-motive elements in the nerves, as well as in the muscles, must be considered as in the condition of a closed circuit, and every current *collected* from a nerve, as *derived* from a current circulating in the nerve itself. Moreover, it is absolutely necessary to avoid any liberation of electricity arising from other sources than from the animal body itself; and without this precaution all experiments would be worthless. Thus, for instance, it would not be a proper manner of examining the nerves or muscles with regard to their electric properties, to connect two conducting wires with the ends of a galvanometer, and then to touch with them a nerve or muscle. By experimenting in this way, under any circumstances, we should find indications of electricity, for no two pieces of metal are ever completely identical; and they would therefore, if placed in contact with the same liquid, give rise to an electric current, the intensity of which would be sufficient to deflect the needle of a sensitive multiplier. But even if the metals were identical, it would suffice to touch the tissues a fraction of a second sooner with one than with the other, for producing an electric current which would be indicated by the needle.

Galvani's Discovery.—Galvani was the first to show experimentally the existence of electric currents in a frog, which he had prepared in a peculiar manner. He killed

the animal, rapidly skinned it, and passed the point of a pair of scissors beneath the two lumbar nerves, which appear like white threads on each side of the vertebral column. The second and third lower vertebræ were then removed, so that the lumbar nerves were laid bare, and formed the only link

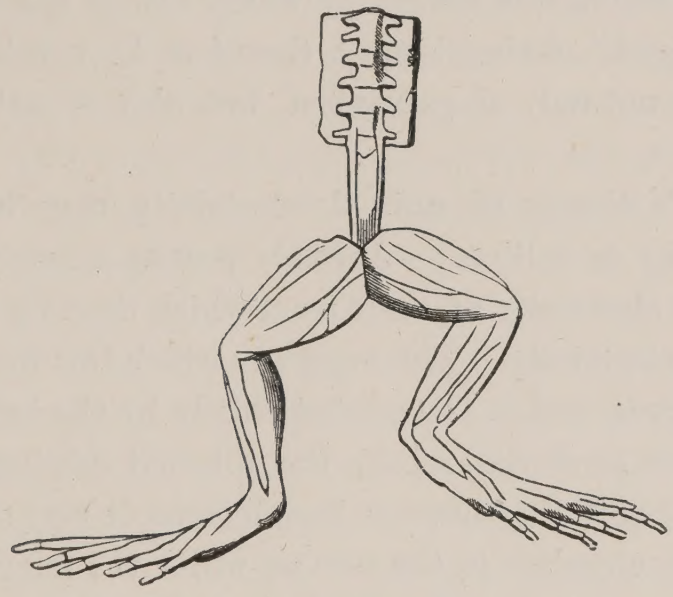

FIG. 40.—Galvani's Frog.

between the hinder extremities of the frog and its upper vertebræ. On connecting the nerves and muscles of the frog by means of an arc composed of two metals, he perceived powerful contractions of the muscles. Volta objected to this experiment, that the electric current thus liberated was due to the contact of the two heterogeneous metals. Galvani therefore connected the nerves and muscles by means of an arc of homogeneous metal, and succeeded equally in producing contractions. But Volta contended that any difference, however slight, in the homogeneity of conducting bodies in contact was sufficient to produce an electric current rendered perceptible by the frog's contractions. Galvani then divided the nerves of the frog at their exit from the vertebral canal, raised them with a glass rod, so as to bring them in contact with the external surface of a frog's thigh, on a single point of the muscle, and the muscles contracted

as before. Volta now endeavoured to prove that the electric current thus produced had its source in the contact of nerve and muscle; but Galvani succeeded at last in bringing about contractions by merely connecting the nerves of two thighs, so that there was no contact between heterogeneous bodies. This contraction was denied by Volta, but is now generally acknowledged. Galvani must therefore be considered the discoverer not only of galvanism, but also of animal electricity.

Galvani's theory of animal electricity may be shortly summed up as follows:—Animals possess a special and independent electricity of their own, which deserves the name of animal electricity. The organs in which this force resides are the nerves, and it is secreted chiefly by the brain. The electricity is conducted along the internal substance of the nerves, probably the thinnest lymph; and it may thus freely and rapidly circulate in the nerves, while the fatty envelope of the latter prevents its dispersion, and allows it to accumulate. The chief receptacles of the electricity are the muscles; they represent, as it were, a Leyden jar, their external surfaces being negative, while the inner ones are positive. The conductor of the jar is the nerve, which, together with the blood-vessels, supplies the muscle with electricity. The mechanism of motion consists of drawing the electricity from the interior of the muscle, and conducting it along the nerves to the external surface of the muscle, where it passes out. Each contraction is, therefore, as it were, accompanied by a discharge of the muscular Leyden jar, and this again causes a fresh contraction, through the stimulation of the irritable muscular fibre by the electricity flowing over the external surface of the muscle.[1]

[1] Pfaff, Ueber thierische Elektricität und Reizbarkeit (Leipzig, 1795), p. 329.

Volta's views, however, were generally accepted by natural philosophers, and it was not until thirty years later that Galvani's experiments were again taken up by M. Nobili,[1] of Reggio, who employed for his researches a sensitive multiplier, and succeeded in showing the existence of an electric current in the frog, which he believed peculiar to that animal. He prepared a frog's limb as usual, immersed both feet in two separate vessels filled with water or salt water, and found that if one of the ends of the galvanometer was placed into each vessel, the needle showed by its deflection the existence of a current moving from the foot to the head, or from the muscle to the nerve. This current deflected the needle to an angle of 30°; and its action on the multiplier was not unfrequently seen to last for several hours. Nobili found that touching the nerve and the muscle of one frog with the nerve and the muscle of another frog, had no effect on the needle, one current being opposed to the other; but if

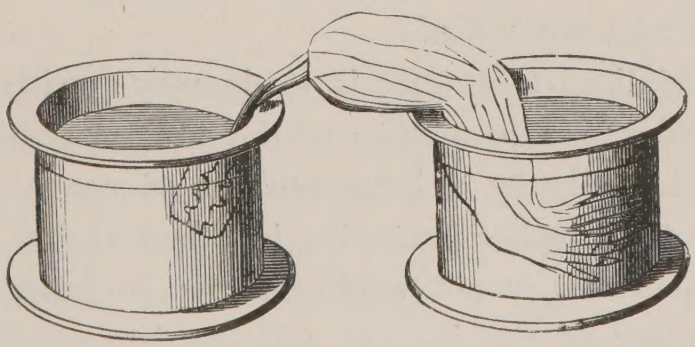

FIG. 41.—Nobili's 'Frog-current.'

the nerve of one frog was placed in contact with the muscle of another frog, a powerful contraction took place.

These researches were further pursued by Matteucci,[2] who discovered that animal electricity is capable of decomposing

[1] Annales de Chimie et de Physique, 1828, vol. xxxviii. p. 225.

[2] Comptes rendus, 1837, vol. v. p. 520. And, Essai sur les Phénomènes électriques des Animaux (Paris, 1840); and Cours d'Électro-physiologie (Paris 1858).

iodide of potassium, of giving signs of tension with a delicate condenser, and of deflecting the needle of the galvanometer; but it was a German philosopher, Professor Du Bois-Reymond,[1] of Berlin, who devised the most ingenious and unobjectionable method of investigating this matter; by means of which he was enabled notably to enlarge our knowledge on this subject.

His views were at one time universally received by physiologists, but have of late years been fiercely assailed from different quarters. As all those, however, who disagree with Du Bois, likewise disagree most flagrantly with each other, we have simply to record the fact that the subject of animal electricity is at present in an unsettled condition; and we think it best provisionally to retain Du Bois' system, until its assailants have made good their case.

For demonstrating the electric properties of nerves and muscles, Du Bois selected a *multiplier* brought to the highest degree of sensitiveness, and the physiological galvanoscope, or *rheoscopic limb*.

The multiplier (G, fig. 42,) is made very sensitive, partly by employing astatic needles of the utmost possible perfection, and partly by a large number of convolutions of the wire. A multiplier possessing less than 11,000 turns of a fine copper wire is not applicable for investigating the current proper of the nerves: and for demonstrating the muscular current in the living man, 24,000 convolutions are necessary. Such an instrument indicates not only the presence and direction of very feeble electric currents, but also certain changes in their intensity. There is, however, this inconvenience, that the magnetic needle is too slow to indicate a current of instantaneous duration, and that it is not able to follow all the variations in the intensity of the current, which sometimes succeed each other very rapidly;

[1] Untersuchungen über thierische Elektricität. Berlin, 1848 and 1853.

for it will only tell the resultant of such variations. It is therefore necessary to have another and more delicate indicator of the current; this is the galvanoscopic frog, or the rheoscopic limb, which is prepared in the following way:—

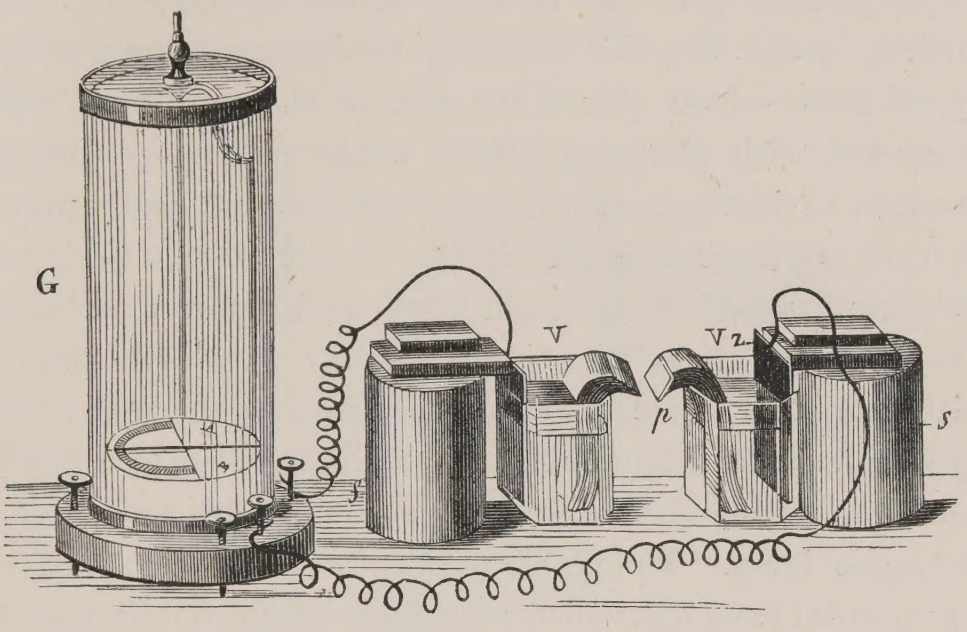

FIG. 42.—Du Bois-Reymond's Apparatus.

A frog is killed, rapidly skinned, and its thigh-bone cut off just above the insertion of the gastrocnemius muscle; all the muscles by which communication is kept up between the upper and lower piece of the thigh are then removed, and the sciatic nerve is prepared as high up as possible towards its origin, and afterwards divided at its upper end so as to remain in connection with the leg. The frog's limb thus prepared indicates the presence of currents of instantaneous duration, even when they move in contrary directions, and succeed each other very rapidly. It has, however, the disadvantage that it soon loses its excitability, and that it contracts only when the circuit is made or broken, but not while the circuit remains closed, so that it does not help us to decide whether there is a continuous current or a momentary discharge. It is, therefore, obvious that the

multiplier and the rheoscopic limb are both necessary for investigating the phenomena of animal electricity.

We have already seen that it is important to avoid bringing into the circuit any heterogeneous substances, which might possibly give rise to a liberation of electricity. In order to avoid this, the following arrangement was adopted by Du Bois:—both ends of the wire of the multiplier were connected with platinum plates, made as homogeneous as possible, as the slightest difference between such plates would of itself originate a current if the circuit were closed, and the plates dipped into a vessel filled with water. To render the platinum plates homogeneous, they were first cleaned with a mixture of alcohol and ether, then washed with nitro-hydrochloric acid, immersed into distilled water, and finally heated to incandescence for half a minute, by means of a Berzelius' lamp. The plates were held in a clamp fixed on a horizontal brass rod, which could be fixed and moved in every position; the free ends of the plates were then immersed in two large vessels (vv, fig. 42) filled with a saturated solution of table salt. But as the salt water would exercise an injurious action upon the tissues if in immediate contact with the same, two cushions (p) made of many layers of fine blotting paper, well moistened with salt water, were immersed with one of their ends into the liquid, and rested against the edge of the vessel—their free ends being outside of the vessel, and the circuit being closed by connecting the two conducting cushions by a third cushion. To avoid the corroding action of salt water upon the animal tissues, a piece of bladder well moistened with the white of an egg was laid upon each cushion.

Du Bois has also constructed platinum electrodes, which consist of two L-shaped platinum pieces, soldered to pieces of a thick brass wire passing through a block of ivory, where a screw secures them, and terminating in a binding screw

for one of the terminal wires of the apparatus. A glass plate prevents the platinum plates from coming in contact with the paper cushions, in order to avoid any passage of the current into the circuit of the galvanometer. The free end of the glass plate is bevelled beneath, so that the plates may be very nearly approached when the nerve piece is short.

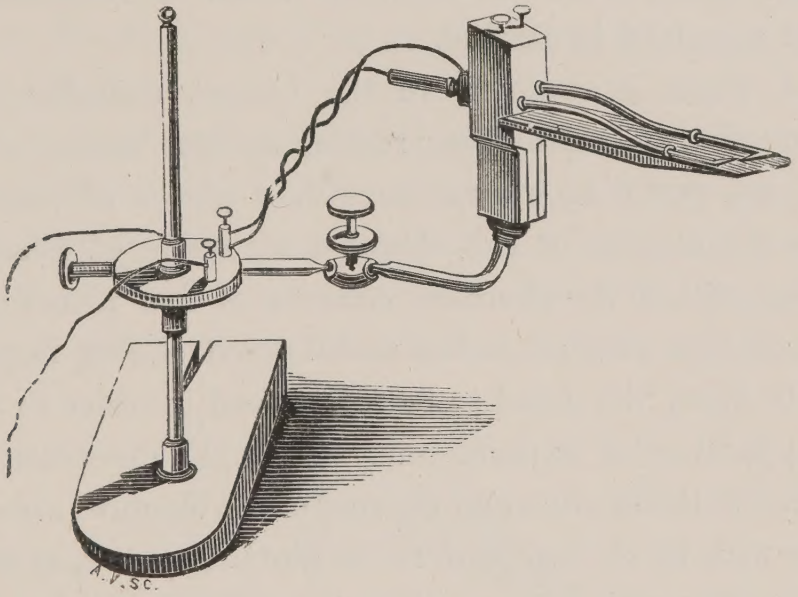

FIG. 43.—Du Bois-Reymond's Platinum Electrodes.

Although this arrangement was a great improvement upon those which had been previously used, it yet appeared that the influence of polarisation was not completely prevented by it. Amongst all metals platinum may be most easily rendered homogeneous; but it has the great drawback of becoming rapidly polarised under the influence of the galvanic current, and therefore yielding unsatisfactory results. Now, M. Regnauld has shown (p. 45) that amalgamated zinc immersed in a solution of sulphate of zinc, is not only perfectly homogeneous, but also unpolarisable by the galvanic current. Du Bois has therefore recently adopted the following modification of his original arrangement:—Two vessels of zinc are used which contain a solution

of sulphate of zinc, and upon which the edges of the cushions are laid. These latter are soaked in a solution of sulphate of zinc, and kept in their places by plates of ebonite connected with the zinc. The inside and edges of the zinc vessels are carefully amalgamated, while their outside is thickly coated with a varnish formed of asphaltum dissolved in turpentine; and the clamp which connects one end of the multiplier with the deriving vessel is varnished with shellac dissolved in alcohol.

The whole is enclosed in the 'moist chamber,' which consists of a mahogany floor resting on four blocks of wood, which are raised up on well-varnished pieces of plate-glass. The roof and sides of the chamber are made of glass. The interior wall of the chamber consists of two pieces of glass touching one another in the middle, and sliding in grooves, so as to allow the hand to be introduced in order to arrange the apparatus for experiments. With the exception of the anterior wall, the sides and the roof of the chamber are covered inside with thick layers of moist blotting paper, so as to fill the chamber with vapour. Two porous cells filled with water are placed on the bottom plate, in order to maintain the moisture of the chamber and to receive any water which may flow off from the cushions. A closing cushion is laid over the two deriving cushions. The animal tissues which are examined are protected from the corrosive action of the zinc solution by interposing between the cushions thin layers of sculptor's clay, which is moistened with a solution of chloride of sodium, in order to increase its conducting power. This is likewise unpolarisable.

The following is the way in which the experiment is conducted:—The two deriving cushions are placed in close contact with one another, and the closing cushion is laid over them; the multiplier is then tested, and if the apparatus is in order no deflection of the needle ought to

occur. If there be any deflection, there must be some fault either in the zinc vessels, or in the conducting liquid, or in the cushions, which must be rectified previous to the experiment being commenced. If there be no deflection, the closing cushion is removed, and the part to be examined placed on the clay-guards; the circuit of the multiplier is then opened, and if there be any current of animal electricity in the part, the needle suffers a deflection indicating the presence, direction, and kind of electricity inherent to the part examined.

Du Bois' *rheophoric tubes*, or clay electrodes (fig. 44, p. 106) allow us to derive in a still finer manner electric currents, without danger of polarisation, from animal structures. They consist of flat glass tubes, the lower end of which is plugged up, watertight, with salt-clay, which exteriorly is modelled into

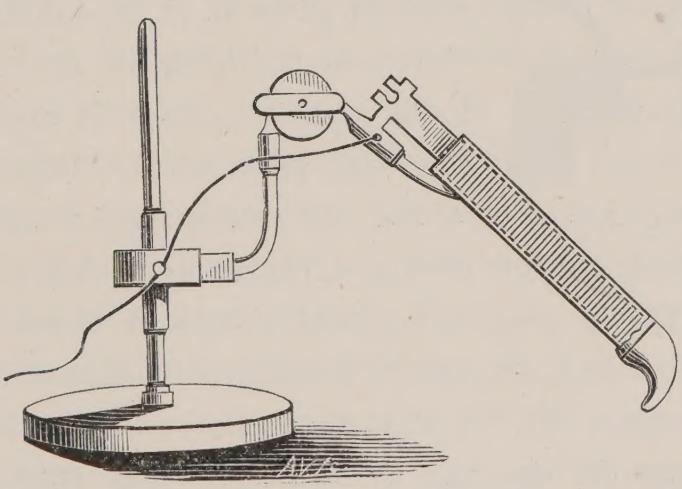

FIG. 44.—Du Bois-Reymond's Clay Electrode.

a sort of spur, with its point working immediately on the nerve or muscle. A different shape, direction, or pointedness may be given to this, owing to its plasticity, at any moment. The tube is connected by a bent glass arm with a piece of brass ending in a socket, so as to have free motion in all directions. From this projects a horizontal brass piece, on which is screwed a strip of the amalgamated zinc plate, immersed in a concentrated solution of zinc sulphate.

Moreover, the brass piece has a screw for attaching a copper wire proceeding to the ivory knob on the brass slider; the object of winding the wire round the ivory knob being to prevent any traction on the wire acting directly on the glass tube, whereby, otherwise, it might be broken.

Dr. Radcliffe [1] has lately recommended the use of electrodes consisting of platinum wires flattened at the end, and thickly coated with moist sculptor's clay; but this would appear to be a step backwards in experimental precision, as we have seen that platinum is a most polarisable metal, and should therefore be eschewed in all delicate electro-physiological observations.

Nervous Current.—If the multiplier has been arranged in Du Bois' fashion, and we now take a fresh piece of the sciatic nerve (p, c) of a frog, and bring various parts of it in connection with the two cushions, we notice the following phenomena:—if any two *symmetrical* parts of the longitudinal or of the transverse section of the nerve are placed upon the cushions, there is no deflection of the needle; if two *dissymmetrical* points of the longitudinal section are taken, we obtain a feeble deflection of the needle, varying from 6° to 7°; and if the nerve be in contact with the cushions on one side by its longitudinal section, and on the other by its transverse section, the needle suffers a deflection varying from 15° to 30°. The current thus indicated moves from the longitudinal section of the nerve through the multiplier to the transverse section of the nerve; and the points which are nearer to the middle of the nervous fragment are positive in respect to those which are nearer to the extremities. The same results are obtained with the galvanoscopic frog; and whether nerves of sensation or of

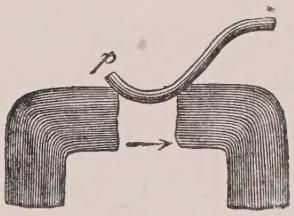

FIG. 45.

[1] Proceedings of the Royal Society, April, 1869.

motion, or mixed nerves, or pieces taken from the spinal cord are examined; as to the brain, every artificial section of it is negative to every point of its natural surface.

Electrotonus.—Great changes are produced in the intensity of the nervous current if one part of the living and excitable frog's nerve be subjected to the action of a continuous galvanic current, another part of the same nerve being placed upon the cushions. The intensity of the nervous current is *increased* if the galvanic current, which is made to act upon the nerve, move in the same direction with the nervous current (*positive phase of the nerve*); and it is *diminished* if the direction of the galvanic current be opposed to that of the nervous current (*negative phase of the nerve*). Du Bois has termed this alteration of the nervous current the *electrotonic state.* This state commences as soon as the circuit of the battery is closed; it remains unchanged all the time that the battery current continues to circulate in the nerve, and disappears immediately on opening the circuit. The electrotonic state is not due merely to the transmission of the battery current through the nerve, but to a real alteration of the electric properties of the nerve; for there is no trace of electrotonus perceptible if a wet thread be interposed between the two parts of the nerve, and tightly drawn together. Under such circumstances the transmission of the battery current is not arrested, but as the continuity of the nervous matter is destroyed, the battery current no longer produces the same effects as previously. Electrotonus likewise fails to appear when the nerve has lost its excitability. From these facts Du Bois-Reymond has concluded that the nerves consist of an innumerable multitude of electric molecules, which are differently arranged according to the different states of the nerves. The electric currents in the nerves show, in some instances, such sudden variations both of intensity and of direction, as to make it impossible

to account for them by any change of larger heterogeneous elements, or in any other way than by assuming corresponding changes of position in almost infinitely small centres of action. When the living nerve is at rest, Du Bois supposes these molecules to be turned towards each other with equal extremities, so that two molecules form, as it were, only one molecule, possessed of one positive zone, and two negative poles. This he calls the *peripolar arrangement.* In the electrotonic state, however, the molecules are thus arranged that unequal poles are turned towards each other; this he terms the *dipolar arrangement.*

Negative Variation of the Current.—Other important changes are induced in the nervous current, as soon as the nerve enters that active state which enables it to cause motion, sensation, and secretion, whatever may be the means by which the nerve is excited. For demonstrating this, the nerve may be tetanised by strychnia, or excited by heating, or bruising its free extremity, which is placed between the cushions. The consequence of such proceedings is that the needle which had been deflected by the nervous current during the peripolar arrangement, returns more or less towards its previous position of equilibrium: that is to say, the nervous current suffers a great and sudden diminution, which Du Bois has called the negative variation of the current. This lasts only as long as the nerve is kept in an excited condition; if it be no longer excited, the previous effects of the nervous current become once more perceptible. The negative variation of the current, however, is not permanent, even when the contraction appears to be so, as in tetanus; but it is, like the contraction, always composed of a rapid succession of single and sudden variations.

When the nerve is no longer able to cause motion, sensation, or secretion, the nervous current appears very feeble, or its original direction becomes inverted, the negative surfaces

being now positive, and the positive surfaces negative. If we now again endeavour to cause the electrical phenomena inherent to the living nerve, we may perhaps succeed in producing a slight degree of electrotonus, but we shall always fail to induce the negative variation of the current. Moreover, the electrotonic state ceases so shortly after the cessation of the excitability of the nerve, that we may say that all the electrical phenomena in the nerve disappear at the same time with its vitality.

Moleschott,[1] who has experimented on this subject, found that, if a nerve had been submitted to the influence of a powerful continuous current and was then tetanised by strong induction currents moving alternately in different directions, there was not unfrequently a positive, instead of a negative variation of the current; and he was therefore led to believe that the active state of the motor nerve was not always accompanied by a negative, but sometimes by a positive variation of the current. To this Du Bois[2] replied that the positive variation which had been observed by Moleschott had nothing to do with the active condition of the motor nerve, but was owing to the natural preponderance of the positive over the negative phase of electrotonus, which is chiefly observed when the nerve has already to some extent lost its excitability, in consequence of having been for some time separated from the body of the animal, and subjected to injurious influences. It seems that Moleschott had omitted to take this fact into consideration. Du Bois, however, was thereby induced to show, by other than electrical means, that the active condition of the nerve is really, and under all circumstances, accompanied by a negative variation, and he has succeeded in proving that the negative variation also

[1] Untersuchungen zur Naturlehre, 1861, vol. viii. p. 1.

[2] Positive Schwankung des Nervenstroms, etc., in Reichert's und Dubois' Archiv, 1861, p. 786.

appears when the nerve is excited mechanically, chemically, or by heat, and that it must therefore be looked upon as the electrical expression of the state of activity in the nerve.

The nervous current may be weakened, diverted, or even totally destroyed by repeated and strong electrical discharges. Opium, morphia, strychnia, prussic acid, and most substances which have a decided chemical action on the nerve, such as ether, alcohol, and mineral acids, rapidly destroy the nervous current; the only exception to this rule being formed by a concentrated solution of arsenious acid, which has a very slow and feeble action on the same. Extremes of cold and heat, desiccation, and imbibition of a large quantity of water, are likewise deleterious to the nervous current.

Schiff[1] considers that the negative variation of the divided nerve does not only represent a diminution of the original nervous current, but also a peculiar process going on in the divided nerve, the direction of which is opposite to that of the original current. He concludes this from the fact that if, in consequence of external circumstances, the original nervous current is accidentally reversed in the divided nerve, the negative variation is not affected by it. The current originating from the excitation, preserves then its original direction, and is positive instead of negative to the original nerve current. This is also confirmed by the following experiments:—If, in mammalia, a long piece of a mixed nerve, such as the pneumogastric or the sciatic, be excised and examined with unpolarisable electrodes fixed at a certain distance, so that they are gradually conducted over the whole length of the nerve piece, a current is obtained which, according to Du Bois' theory, must reverse its absolute direction at the equator of

[1] Pflüger's Archiv für Physiologie, 1872, p. 437.

the nerve piece. The nervous current travels here on both sides in the direction of the transverse section to the equator. Now, it is very frequently found in such cases that this equator for the nervous current at rest, is considerably displaced towards one side, so that in the nerve the current proceeding from the transverse section *A*, rules a far longer piece than the current proceeding from the transverse section *B*. Now, if the negative variation were really a modification induced by the excitation, or, as Du Bois says, 'a motor phenomenon' of the original nervous current, it ought to obey the same law as the latter; that is to say, it ought to reverse its apparent direction at the same displaced equator. If the same nerve be now examined once more in the manner just described, by exciting the extreme end of the nerve after each deflection of the galvanometer, and we then observe the modification of the deflection which is caused by the excitation, it is found that this modification is not everywhere negative. The process of excitation causes a negative variation in the nerve up to a certain point, but after that the direction of the current is reversed. It has proceeded beyond the equator of the exciting current, and the latter becomes positive to the nervous current at rest up to the point where the equator of the nervous current at rest is situated. From this point, the process of excitation becomes again relatively negative without changing its direction. It is, therefore, evident that the exciting current has here its own equator which is independent of the equator of the nervous current at rest. The electric expression of the excitation of the divided nerve is, therefore, a special current which is independent of the original nervous current of the same nerve, and does not invariably or necessarily cause a negative variation of the same. It often occurs in recently killed dogs and cats, that in the excised long nerve piece, the equator of the nervous

current at rest is displaced from the middle to the point of section A, and the equator of the exciting current to the point of section B, so that the exciting current causes a positive variation in the largest portion of the middle piece of the nerve. It is true, that in nerves which are perfectly fresh, the two equators are very close together in the middle of the nerve piece, and under these circumstances, the exciting current shows almost everywhere the phenomenon of the negative variation.

Schiff also believes that the negative variation is only produced by excitation of those nerves which already possess a perceptible current in consequence of injury. In the uninjured nerve, which appears externally devoid of a current, any excitation causes an extremely feeble current the direction of which is always from the periphery to the centre, whether the nerve be sentient or motor, whether the excitation be made on the central or on the peripheral side of the point connected with the galvanometer, and whether the excitation causes a movement or not. This centripetal current is, according to Schiff, the real expression of functional activity in the uninjured nerve.

Muscular Current.—For investigating the electric properties of the muscles, Du Bois-Reymond selected likewise the multiplier and the galvanoscopic frog. But as the muscles produce currents of far greater intensity than the nerves, the multiplier must not possess so many convolutions as that intended for demonstrating the nervous current (4,000 to 6,000 instead of 24,000). The muscular current appears to be perfectly analogous to the nervous current, except that it is stronger. We do not perceive a deflection of the magnetised needle if the muscle (a, b) is placed upon the cushions

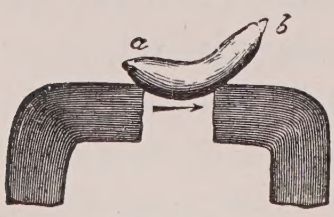

FIG. 46.

with two symmetrical points, whether of the longitudinal or of the transverse section; but the more dissymmetrical the two points, the stronger is the deflection of the needle; and the current appears strongest when a portion of the fleshy surface of the muscle is laid upon one of the cushions, and a portion of the surface formed by cutting the muscles across, upon the other—that is to say, between the natural longitudinal section and the artificial transverse section.

It should be understood that the tendinous portion of the muscle is its *natural transverse section*, and that the fleshy surface of the muscle is its *natural longitudinal section*. The *artificial transverse section* is produced if the muscle be divided perpendicularly, and the *artificial longitudinal section* if the muscle be torn in the direction of its fibres.

The direction of the muscular current is the same as that of the nervous current. In the living muscle each point of the longitudinal section, whether natural or artificial, is positive in respect to each point of the transverse section, whether natural or artificial. Each time that a conducting arch is established between any point of the longitudinal section of the living muscle, and any point of its transverse section, the needle indicates a current in this arch, moving from the longitudinal section to the transverse section. This law has been established on the muscles of the frog, and verified on the muscles of an amputated leg of a man, on the muscles of rabbits, mice, sparrows, and of the common earth-worm; and it has been shown to rule not only the entire muscle, but a single primitive bundle.

The variations in the intensity and direction of the muscular current are, in certain instances, so sudden and so extensive, that we are compelled to assume corresponding changes of position in the molecules of the muscle, which are analogous to those supposed to occur in the molecules of the nerve.

Muscular Current in the Living Man.—It is more difficult to demonstrate the muscular current in man than in the muscles of a frog, because the resistance offered by the skin of the human body diminishes the action on the magnetic needle. The deflections become more extensive when the cuticle is removed, or the portion of the body experimented upon placed in communication with the salt water which closes the circuit. For showing the existence of the muscular current in man, a multiplier of 27,000 to 30,000 convolutions is required. Care must be taken to exclude any currents arising from other sources, such as from the unequal transpiration of the skin on two points placed in connection with the multiplier, from inequality of temperature, from the want of simultaneity in establishing the contact of the two points placed in the circuit, &c. When the cuticle was removed by a blister applied to the arm, and the denuded corium placed in communication with the multiplier, Du Bois-Reymond obtained a current of 60° to 70°, whilst, if the skin in its usual state communicated with the galvanometer, the deflection of the needle was only from 2° to 3°.

Parelectronomic Layer.—An analogous phenomenon is observed in the frog. When the animal has been skinned, it is easy enough to demonstrate its muscular current; but if the skin be left intact irregular results are obtained, which are partly owing to the circumstance that the skin possesses an electromotive force of its own. In order to show the muscular current in all its intensity, the surface of the muscle should be moistened with salt water. As long as the tendon of a fresh muscle is touched merely by blood or lymph, the current passing from the longitudinal to the transverse section is very feeble. Its intensity is increased if the tendon be immersed in some other liquid, or if the tendon be totally removed or destroyed by a porcelain cautery. Hence it

results, that the fresh muscle, as long as it is only in contact with blood and lymph, possesses a superficial layer, which more or less prevents the manifestation of the contrast between the longitudinal and transverse section. Du Bois-Reymond has, therefore, termed it the *parelectronomic layer*.

The parelectronomic layer exists in different proportions in different animals. It is most complete in frogs which have been for some time subjected to the temperature of melting ice; in the muscles of these animals there is either no current at all, or an inverse current, due to the preponderance of the parelectronomic layer. But even under these circumstances, the current may be instantly revived if the tendon be touched with water, albumen, alcohol, acids, alkalies, or salt water. The muscles of mammalia, birds, and fishes, present the same property, although in a less degree.

Induced Contraction.—The phenomenon comprehended under the name of *induced* or *secondary contraction*, was first observed by Matteucci. He prepared a frog in Galvani's manner, and placed upon its thighs the nerve of another rheoscopic limb, uniting both, as it were, by a bridge. A continuous current was then sent through the lumbar nerves of the first frog, which caused a powerful contraction, not only of the limbs of the first frog, but also in the second preparation, the nerve alone of which was in contact with the thighs of the first frog. Du Bois has succeeded in inducing a contraction of the third, fourth, fifth and sixth order, in rheoscopic limbs, which communicated with each other merely by the nerves. These induced or secondary contractions are owing to variations of the density of the current in the rheoscopic limb. No or little effect is obtained, if the nerves be made to communicate with two points symmetrically situated in the muscle; but

in order to produce a decided result, the two points of the nerve should be laid upon points of the muscle which are as dissymmetrical as possible.

Matteucci's contraction appears to obey the general law of the muscular current, being strongest when the most effective arrangement for the latter is used, that is, when the nerve of the rheoscopic limb is made to touch the natural longitudinal and the artificial transverse section of the muscle; and it is feeble when a weak arrangement is employed, that is, when the nerve is made to touch other sections.

The intensity of the muscular current diminishes after death proportionately to the degree of excitability possessed by the muscles. It disappears more rapidly in warm-blooded animals than in reptiles and fishes. As soon as *rigor mortis* sets in, which Brücke has shown to be owing to the coagulation of the liquid fibrine contained in the muscles outside of the blood-vessels, both the excitability of the muscles and their electro-motive force disappear equally, never to appear again, not even when rigidity has ceased in consequence of decomposition of the fibrine.

The muscular current is therefore inherent to the living and excitable animal tissue.

In warm-blooded animals, such as the dog and the rabbit, it sometimes disappears within half an hour after death, while in a frog's limb, which is carefully protected from injurious influences, and kept at a low temperature, it may sometimes continue for a fortnight or even a month. It also varies with the seasons. Winter is more favourable to its persistence, while hot weather often causes it to disappear rapidly. In frogs the irritability lasts longest in spring, previous to spawning-time.

The local application of poisons to the nerves and muscles appears to be more effective in altering the muscular current

than their introduction into the system. Prussic acid, extract of opium, the acetates of morphia and of strychnia, and veratria, when brought in direct contact with the muscular substance, render it rapidly rigid, and acid, and deprive it of its natural electricity. Substances which have a considerable chemical action on vitalised tissues, such as mineral acids, alcohol, ether, nitrate of silver, and creasote, utterly destroy the texture, and simultaneously with it the electro-physiological properties of the muscular fibre.

Matteucci affirms that poisoning by woorara diminishes the intensity of the muscular current; but this is denied by Claude Bernard, von Bezold and Kölliker.[1]

Dr. Radcliffe[2] sees reason to believe that the primary electrical condition of living muscle and nerve during the state of inaction is that of static electricity, and that the muscular current and the nervous current, which may pass from the muscle or nerve during the state of inaction, are only secondary phenomena. He believes, with Matteucci, that the state of action in a muscle and in a motor nerve is accompanied by a discharge of electricity analogous to that of the torpedo; and that when a muscle is made to contract by means of its nerve, the electrical discharge which accompanies nervous action has reversed the electrical relations of the exterior and interior of the muscular fibres in the part acted upon; that this reversal has led to the discharge of the electricity which is present in the muscular fibres during the time of rest, and which keeps these fibres in a state of relaxation as long as it is present; and that this discharge of electricity causes muscular contraction by leaving the muscle free to yield to the action of the attrac-

[1] Comptes rendus, vol. xlviii. p. 1145. Leçons sur la Physiologie, etc. Reichert's Archiv, p. 168.

[2] Lectures on Epilepsy, Pain, Paralysis, and certain other Disorders of the Nervous System, London, 1864; and The Dynamics of Nerve and Muscle, London, 1871.

tive force which is inherent in the physical constitution of the muscular molecules. Dr. Radcliffe has supported his views by an elaborate argumentation, but he has not succeeded in rendering them acceptable to physiologists.

Not only the nerves and muscles, the brain and the spinal cord of the living animal, are possessed of electro-motive force, but all tissues in which active nutrition is going on give rise to electric currents. Pieces of lung, liver, and kidney, cause weak currents, which partially obey the laws of the muscular current, and which continue long after death. Currents of animal electricity have also been discovered in the intestines of the frog, the iris of birds of prey, the ovary of the rabbit, the oviduct of the frog, the ureter, urinary bladder, and aorta of the rabbit, and the spleen, testicles, tendons, and bones of the frog. These currents have one point in common with the muscular current, viz. that the external and internal surfaces of these tissues are inversely electrified. In no other tissue, however, is the electro-motive force so strong, nor are there such great and sudden variations in the intensity and direction of the current, as in the nerves and muscles.

The Glandular Current.—Du Bois has found that when the two extremities of the galvanometer are made to touch the external surface of the skin of a frog by means of paper cushions moistened with salt water, a strong current travels from the point which was last touched to that which was first touched. The needle, however, gives no indication of a current, if the contact is as far as possible simultaneous. The current obtained by the first proceeding disappears rapidly, as the salt solution destroys the electromotive force of the skin. On examining the internal surface of the skin a regular but feeble current is observed to travel from the point first touched to the one last touched; and, if the extremities of the multiplier are applied at the same time to

the external and internal surfaces, a current is noticed to pass from the external to the internal surface. This latter current also disappears rapidly, from which Du Bois has concluded that the skin of the frog possesses an electro-motive force acting from the external to the internal surface, and which is readily destroyed by the application of salt. Solutions of chloride of ammonium, iodide of potassium, sulphate of zinc, sulphate of copper, diluted sulphuric acid, liquor potassæ and liquor ammoniæ, also destroy this electro-motive force in a short time.

Du Bois has found that these cutaneous currents are peculiar to the naked amphibia, and do not occur in fishes; he therefore thinks that they are connected with the secretion from the glands of the skin, which is very abundant in frogs and toads. They are vital phenomena, for the skin taken from a frog in a state of putrefaction does not show any electric currents at all.

Budge [1] has more recently investigated these conditions, and has come to the conclusion that the longitudinal section of the frog's skin is negative to its transverse section. He found that when a piece of frog's skin is rolled up into a thin cylinder, and a transverse section is made, the needle is deflected to an angle of from 50° to 80°, if the extremities of the multiplier are brought into contact with the longitudinal and transverse section. If the cushions are moistened with a solution of sulphate of zinc, the current remains very constant for some hours, but disappears rapidly when a solution of chloride of sodium is used. Budge also found that the rheoscopic limb may be made to contract by this current.

Rosenthal,[2] who repeated these experiments, has shown

[1] Ueber den galvanischen Strom, welcher sich in der Haut des Frosches zu erkennen gibt. Poggendorff's Annalen, vol. cxi. p. 537.

[2] Reichert's and Du Bois-Reymond's Archiv, 1865, p. 301.

that when the cushions are moistened with a solution of sulphate of zinc, a strong current is perceptible in the frog's skin, travelling from without inwards. This current only slowly diminishes in intensity, and even less so if clay-guards are interposed between the cushions for protecting the skin. He discovered another current flowing from the external surface to the transverse section, this being weaker than the one just mentioned; and a third, moving between the internal surface and the transverse section, this latter being the weakest of all. He thinks that these latter currents are artificial productions, and that the electro-motive force really inherent in the frog's skin is the one moving from without inwards. He agrees with Du Bois in assuming that the layer of secreting glands is the source of this electricity, just as the current observed in the stomach of the frog and the rabbit, which also moves from the excretory ducts of the glands to the glandular substance. It might be objected to this view that the electricity was merely derived from chemical action, since the mucus secreted by the glands of the frog's skin, and the gastric juice, are both acid, while the deeper layers of the skin and stomach are alkaline; but this objection is removed by Du Bois having proved that these vital currents are much stronger than those of the most powerful acid and alkali pair. The chemical composition of the mucus has therefore little or nothing to do with the glandular electricity, which seems indeed to be entirely owing to the living glandular tissue itself. The circumstance that some other glands do not show any electro-motive signs is explained by Rosenthal as arising from their more complex structure, which does not allow the electricity, although it really exists, to make any outward manifestation. Experiments undertaken by Rosenthal and Valentin render it probable that the glandular current, just as the muscular current, experiences certain definite variations when the

nerves animating the glands are galvanised. Grünhagen[1] has lately given a different version of the electrical conditions of the frog's skin; but Rosenthal's experiments and argumentation recommend themselves more to our acceptance, as sources of error seem to have been more carefully excluded in his investigations than in those of Grünhagen.

Cutaneous Currents in Man.—It is easy to discover indications of electricity on the human skin; but not every electricity that is observed there is true animal electricity. A thermo-electric current may be produced by unequally heating two symmetrical parts of the skin, for instance, the corresponding fingers of the two hands. A finger at the temperature of 32° F. is strongly positive to one at 90° or 98°, while a finger at 60° is feebly positive to one at 80°, and strongly so to one at 120°. The electro-motive force of these thermic currents is greater than that of a thermic copper and iron pair, and lasts as long as differences of temperature continue to exist.

If two fingers which are of the same temperature be simultaneously immersed into the vessels of Du Bois' apparatus, there does not appear to be complete homogeneity between them; for, after some irregular oscillations of the needle, a feeble but constant current is observed, flowing in the same direction for months consecutively. This current varies considerably in different persons, both in direction and intensity. It is sometimes found that in the same person the direction becomes suddenly reversed, and the current will then flow for some months in an opposite direction to that which was first observed. This electric current is called *the individual current of the finger.* Again, if two equally warm fingers are immersed into the testing-vessels, not simultaneously, but the one some time after the other, it ap-

[1] Ueber die elektrischen Ströme der Froschhaut. Henle und Pfeuffer's Zeitschrift, vol. xxvii. p. 268.

pears that the finger immersed last is strongly positive to the other. The same may be observed if, instead of the fingers, the two hands, feet, or elbows are immersed. After a time, however, this current gives place to the 'individual current,' unless one part be more deeply immersed than the other, or its position be otherwise changed. This current retains its character, if ordinary water instead of salt water be used, but its direction is reversed in diluted sulphuric acid, and extremely irregular in a solution of potash or of acetate of soda.

These currents which arise from dissimultaneous immersion are quite different from the thermic currents; the former are stronger than the latter, and the direction of the latter is not changed in diluted sulphuric acid. They may, however, both appear simultaneously in the same experiment. Dissimilar stretching of the skin, and dissimilar perspiration, may also give rise to electro-motive action.

After eliminating all these sources of electricity, Du Bois found that, if the electricity inherent to the skin is examined, it appears that the palm of the hand is strongly negative to its back, and the entire hand negative to the elbow and the chest. The elbow is feebly positive to the chest. The sole of the foot is strongly negative to the back of the foot, and the whole foot negative to the chest. The hand is generally negative to the foot, but sometimes the reverse is observed in the beginning of the experiment. All these currents are strong and constant. They are not thermic currents, because their direction is not changed if one of the testing vessels is heated first to 60° and then to 80°, while the other is heated first to 80° and then to 60°. Nor are they traces of the muscular current, for they appear right through the hand and the foot, where a strong muscular current could not exist; and they do not show any negative variation, from which it appears that they must be

simply cutaneous currents, similar to those which are observed in the frog's skin.

Gastro-hepatic Current.—We have seen that the electrical properties of the tissues are in direct proportion to the activity with which the general metamorphosis of matter is being carried on in them. Electricity is everywhere manifested where a disturbance is going on in the equilibrium of molecules; but we must take care not to confound the true animal electricity, which is a vital phenomenon, with electric currents arising merely from chemical action, and which may be observed in dead as well as in living animals, and in vessels filled with heterogeneous liquids as well as in the animal body. A current of this latter kind is Matteucci's gastro-hepatic current.

This philosopher believes that metal salts, when introduced into the blood, are decomposed; the acids being attracted and excreted by the kidneys as electro-positive organ, while the alkalies are drawn to the liver as electro-negative organ; and that the contrary electric states of these organs are the cause of the chemical dissimilarity. In order to show the existence of a current moving from the stomach to the liver, Matteucci introduced a platinum plate into the stomach of a living rabbit; placed another plate on the liver, and connected both of them with the extremities of a galvanometer. The needles instantly traversed an arc of 20°, showing the existence of a powerful current between the liver and the stomach. He now endeavoured to decide the question whether this current should be considered as the effect or the cause of the chemical differences alluded to, since it is generally known that an electric current is developed, if an alkaline and an acid liquid be separated by permeable structures; and the stomach contains an acid, the liver an alkaline secretion. He divided the nerves and vessels passing into the abdomen above the diaphragm, and

observed that the needle deviated only to 3° or 4°, instead of 20°; and after he had cut off the head of the rabbit, hardly any deflection was obtained. But if a wire was inserted into the spinal cord, and muscular commotions were produced, the gastro-hepatic current was temporarily re-established.

From these experiments Matteucci concluded that the gastro-hepatic current was not the effect, but the cause, of the chemical metamorphosis of the saline ingesta, the decomposition of which furnished acid to the stomach and alkali to the liver; that it was not yet known how this current was excited, but that a current unquestionably existed between the stomach and the liver, which would nearly cease on division of the nerves, and completely vanish with the death of the animals. This current he believed to be competent to the evolution of sufficient free acid in the stomach, to enable digestion to go on, an equivalent of soda being determined to the liver.

These experiments and conclusions have since been controverted by M. Donné, who has shown that the so-called gastro-hepatic current may be observed in dead as well as in living animals; from the liver of one rabbit to the stomach of another, and *vice versâ*; that neither the section of nerves and vessels, nor cutting off the head, nor the mechanical or electric excitation of the spinal cord, has any influence on its intensity; that unequal organs, removed from the body and held in the hands, continue to give rise to electric currents; and that, finally, the gastro-hepatic current is an artificial electro-chemical phenomenon, and has nothing to do with true animal electricity.

CHAPTER II.

ELECTRO-PHYSIOLOGY.

I NOW proceed to describe the physiological effects produced by the application of electricity to the different tissues and organs of the living body in their normal condition. I shall successively consider its action upon the brain and the spinal cord, the sympathetic nerve, the organs of special sense, the sentient nerves, the motor nerves and the muscles, the contractile fibre-cells, the heart, the blood, the skin, and the bones. A thorough knowledge of these phenomena will enable us to form more accurate notions of the value of electricity in its application to disease, than might otherwise be obtained. The literature of this subject is, however, now so extensive that it would be quite impossible to refer, within the limits of the present chapter, to all the books and papers which have been written upon it; and it must therefore suffice to give the results of those investigations which are either of great historical interest, or have a direct and important bearing on the therapeutical application of electricity.

All electro-physiological phenomena are dependent, partly upon the electricity itself, and partly upon the property and function of the organ that is submitted to its action. In the first instance, the *form* of electricity which is used is of great importance. Thus, sparks from the common electrical machine applied to the skin of any part of the body produce a sensation of pricking and pain; if they are large, the skin

becomes red, and a papular eruption resembling lichen urticatus is produced. If a continuous current be made to act upon the skin, a sensation of pricking and heat, redness, inflammation, and sloughing of the skin and the subjacent structures may be caused, provided the current be powerful and the application prolonged. A volta-faradic current may produce sensations varying, according to its intensity, from a slight pricking to an acute burning pain; but, although the tension of the current may be very high, it will not cause nutritive disturbances like the continuous current.

Sparks from the common machine, applied to the face, produce a faint sensation of light. The continuous current directed to the face causes a more or less brilliant flash, and if it have a certain degree of intensity, the sensations of light become positively dazzling. An induced current applied to the face produces no sensation of light, but contractions of the muscles and more or less severe pricking sensations.

Besides the form, the *quantity* and *tension* of the electricity have an important bearing on the production of the physiological effects. A powerful application of electricity causes more striking effects than a gentle one. If an induced current of low tension be employed, feeble contractions of the muscles take place, but the sentient nerves are not much affected; on the other hand, a current of high tension causes not only muscular contractions, but also striking sensations of pricking and heat; and if the intensity of the current be very high, pain is felt which would not be relished by the most hardened garotter; and muscular contractions are observed which resemble the commotions of tetanus.

The physiological effects caused by electricity differ likewise according to the *mode* in which electricity is transmitted to the organs. An induced current, applied to the skin by *moistened* conductors, produces contractions of the

muscles which are beneath that part of the skin to which the electrodes are directed. On the other hand, when dry metallic electrodes are used, the sentient nerves of the skin are chiefly affected, while the contractile power of the muscles is only called into play if the tension of the current be very high. When the electrodes are firmly pressed against the skin at a point where a motor nerve approaches the surface, contractions of all the muscles take place which are animated by that nerve; but if the conductors are only just made to touch the skin, the current runs along the subcutaneous cellular tissue, and no muscular contractions are observed.

The *length of time* during which electricity is allowed to act on the different organs, is likewise of importance. If a continuous current of moderate power be directed to the skin for a short time, it dilates the blood-vessels and promotes circulation; but if it be applied for several hours successively (as is often done with Pulvermacher's chains and galvanic belts), the blood-vessels become paralysed, and sloughs are produced. An induced current conveyed for a short time to the motor nerves and muscles, rouses their vital energy; but if its action be prolonged for an hour or more, the motor power of those organs becomes exhausted, and temporary paralysis may be the result.

The physiological effects of electricity are further determined by the *special property of the organ* to which it is applied. The same electric current which produces a flash of light when applied to the eye, causes a special sensation of taste when directed to the tongue; sounds when applied to the ear; muscular contractions, when directed to a motor nerve, and sensations of pricking and heat when applied to the skin. Finally, the different states of vitality of the organ, at the time when the electricity is conveyed to it, are of great importance. Thus, a morbid increase of sensibility

in a nerve, such as occurs in sciatica, tic douloureux, and other forms of neuralgia, may be reduced; while, on the other hand, a nerve, the vital energy of which is gone or materially diminished, may by electricity be restored to its normal condition.

In electro-physiological phraseology the terms *direct*, *descending*, or *centrifugal* current, mean that arrangement of the electrodes in which the positive is nearest to the centre, and the negative at a more peripheral part; and the terms *inverse*, *ascending*, or *centripetal* current, mean that arrangement in which the negative electrode is nearest to the centre, and the positive at a more peripheral part.

The instruments principally used in electro-physiological researches are a few cells of Daniell's battery (p. 27), a Siemens's rheostat (p. 54), a Du Bois-Reymond's induction

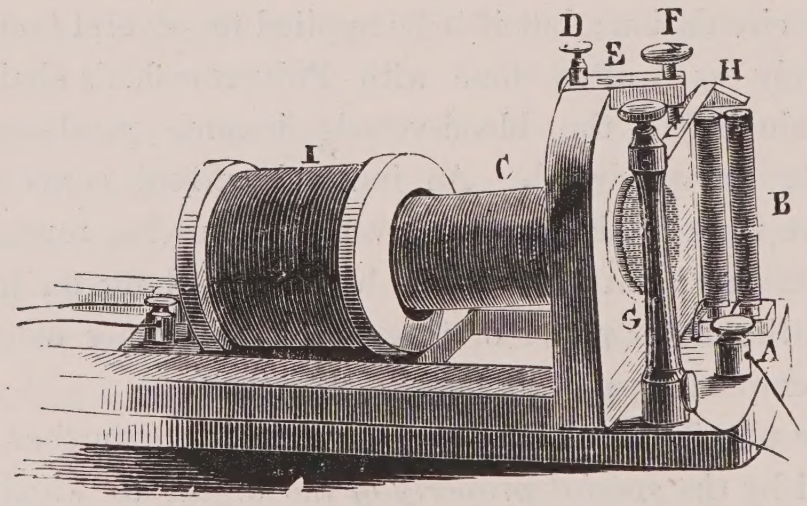

FIG. 47.

Du Bois' Sledge.

apparatus, or, as it is commonly called, 'sledge,' the same observer's galvanic key, and a variety of small electrodes.

Du Bois' sledge is an induction apparatus nursed by a pair of Grove's or Bunsen's battery. A is a clamp for receiving the negative wire of the battery; B a spiral of wire wound round a soft iron in the form of a horse-shoe; C the coil

filled with a core of soft iron, and surrounded by a helix of copper wire, and D the end of this wire. E is a piece of brass which supports D and the platinum-pointed screw F. The positive battery-wire is fastened to the brass pillar G, which at its top is connected with the hammer H. I is the sledge, or outer coil of wires, which may be made to slide on brass rails over part or the whole of the inner coil C. From this description it is easy to follow the way of the current. The positive current first runs through the brass pillar G to the hammer H, and from there to the platinum-pointed screw F; thence it goes to the brass-piece E, and through the clamp D to the inner coil C. It now passes to the small horse-shoe magnet B, traverses both pillars, and at last reaches the negative pole of the battery A. As long as it traverses the wire coiled round the horse-shoe B, it renders the soft iron magnetic, and the latter then attracts the hammer H. This breaks the contact between the hammer and the platinum-pointed screw F, and therefore interrupts the metallic circuit. The magnetism of B thereupon ceases, the hammer is no longer attracted, and returns to its previous position in contact with F. The metallic circuit is thereby re-established, the magnetism reproduced, and the hammer again attracted. The same play is thus constantly repeated as long as the apparatus is in action. The more the external coil I is pushed over the internal coil C, the greater becomes the intensity of the current, and *vice versâ*.

Du Bois' galvanic key (fig. 48, p. 130) is very convenient for opening and closing the circuit of the battery. It consists of a plate of ebonite secured to a vice-pin, by which it can be firmly screwed to the edge of a table. On this plate are fastened two double binding-screws, which can be connected or disconnected by raising or lowering the movable brass arm at the top of the plate. This arm has an ivory handle, and

turns on a pivot. If one battery wire be fixed in the left, and the other in the right binding-screw, the key will open and close the circuit. On the other hand, if the conducting wires be fixed in the outer ones of the pair of binding-screws, and the two inner ones be attached to wires proceeding to the nerve, it is merely necessary to raise the lever in order to make the battery-current pass through the nerve. The advantages of this key are, that it is always ready for use; that the circuit can always be opened and closed with certainty and in the same manner; and that no special consideration need be paid to the battery or the conducting wires.

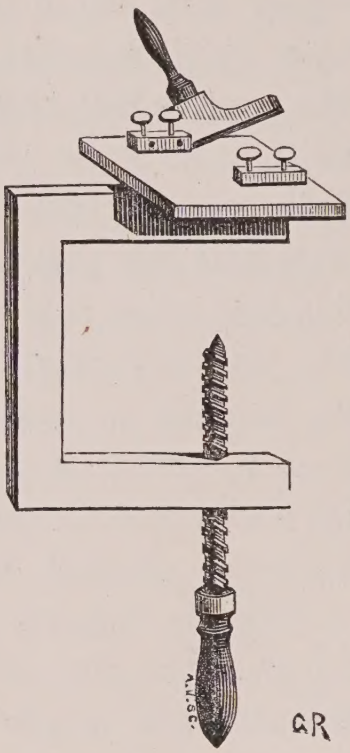

FIG. 48.
Galvanic Key.

I.—ACTION OF ELECTRICITY UPON THE BRAIN.

The only form of electricity which, if applied in moderate intensity, has a distinct physiological action on the brain of the living man, is the continuous current. Static electricity, electro-magnetism, and magneto-electricity, only affect that organ if applied so powerfully as to interfere with health, and perhaps life; but a gentle continuous current, directed to the face, scalp, or neck, and which causes no, or scarcely any, sensation of pain, is readily transmitted from those parts to the cerebral substance. This is shown by the sensations of light, sound, smell, and taste, perceived on applying the continuous current at a distance from the organs of special sense, and which may be explained by assuming that the nerves animating those organs are encountered by the

galvanic influence at the base of the brain. Furthermore, sensations are caused by an application of the current to the head, which can only be owing to a direct action of it on the cerebral matter, viz. dizziness, giddiness, sleepiness, sickness, faintness, vomiting, and even convulsions. The latter phenomena are only noticed if the current be one of considerable power; but giddiness and faintness are often felt even when a gentle current is used.

Up to a recent time it has been generally assumed that the hemispheres of the brain are not excitable by any stimulants which are generally used by physiologists. It is true that Haller and Zinn[1] spoke of having seen convulsive movements after injuring the medullary substance of the brain; but this statement has always been rejected, inasmuch as it was difficult, with the methods of experimentation generally used at that time, to properly localise the action of stimulants; and it was, therefore, believed that they had with their instruments irritated the medulla oblongata.

Longet,[2] who experimented on dogs, rabbits, and goats, irritated the white matter of the cerebral hemispheres with the knife, cauterized it with potash and nitric acid, and sent a galvanic current through it in every direction; but found that all of these proceedings failed to call into action the involuntary muscular contractility. He obtained the same negative results on irritating the gray cortical matter. Magendie likewise found the cerebrum and the cerebellum completely unexcitable to electricity.

Matteucci,[3] on applying the electrodes of a battery of sixty pairs of plates to the cerebral hemispheres, noticed that the animal did not start, nor was any effect visible if the cere-

[1] Mémoire sur la nature sensible et irritable du corps animal. Lausanne, 1756, vol. i. p. 201.

[2] Anatomie et pathologie du système nerveux, etc. Paris, 1842, vol. i. p. 644

[3] Traité des phénomènes électro-physiologiques des animaux. Paris, 1844, p. 272.

bellum was touched; but when the electrodes were directed to the tubercula quadrigemina and the crura cerebri, the animal cried out lustily, and at the same time all the muscles of the body were contracted. These phenomena lasted for several seconds, but did not recur on breaking the current.

Prof. Weber,[1] of Leipzig, used faradism in his researches. He observed no effects if the electrodes were applied to the hemispheres of the brain or to the cerebellum, not even if they were pushed into the depth of the medullary substance; but by directing them to the tubercula quadrigemina, irregular convulsions were produced, which either appeared as clonic cramps, such as are observed in patients suffering from certain diseases of the brain; or which resembled reflex movements, that is to say, they did not occur irregularly in all the muscles, but in certain groups of muscles which are physiologically combined in action. Faradisation of the medulla oblongata caused tetanic convulsions, as observed after poisoning by strychnia.

Van Deen[2] denied any electric excitability to the brain, as well as to the spinal cord of rabbits. Budge, who sacrificed an enormous number of dogs and rabbits, came to the conclusion that not a single motor fibre proceeded from the cerebral hemispheres to the voluntary muscles; and Schiff[3] affirmed that stimulation of the cerebral lobes, of the striated bodies, and the cerebellum, does not cause a trace of a contraction in any of the voluntary muscles of the body or even the viscera.

Flourens,[4] who made a large series of researches on birds and mammalia, in which he successively removed the diffe-

[1] Article 'Muskelbewegung,' in Wagner's Handwörterbuch der Physiologie, vol. iii. part 2.

[2] Moleschott's Untersuchungen, vol. vii. p. 381.

[3] Lehrbuch der Physiologie. Lahr, 1858, vol. i. p. 362.

[4] Recherches expérimentales sur les propriétés et les fonctions du système nerveux. Paris, 1842.

rent portions of the brain, found that volition and consciousness appeared completely lost after ablation of the cerebrum, but that stimulants acting from without would even then cause a kind of purely mechanical movement in the muscles. Animals would run if pushed; birds would fly if thrown up into the air; they would resent worry; would swallow anything put in their mouth; and the iris would contract when exposed to light. But such movements never occurred without the action of some external excitant. Animals deprived of the brain would, as a rule, sit quite still, in a sort of lost and dreamy condition; and they would continue in this state if they were near starvation, and put in the midst of plenty. Flourens concluded from these observations that the cerebral hemispheres are not the seat of the immediate principle of muscular movements, but that they are the centre of volition and sensation.

Quite recently the view that the cerebral hemispheres do not respond to the influence of electricity by muscular motions of remote parts, has been controverted by Fritsch and Hitzig.[1] Their investigations, although as yet not corroborated by other observers, nevertheless appear to have been most carefully made; and will, if confirmed, profoundly modify the opinions we have hitherto entertained regarding the localisation of the cerebral faculties. Hitzig was led to undertake these researches from having observed movements of voluntary muscles in consequence of direct galvanisation of the nervous centres in the living man. He found that if a constant current was passed through the posterior portion of the head, certain movements of the eyes occurred which could only be owing to direct excitation of cerebral centres. They might have been looked upon as caused by stimulation of the corpora quadrigemina, or neighbouring parts; but as

[1] Reichert und Du Bois-Reymond's Archiv, 1870, p. 300.

they likewise took place when the current was passed through the temples, if only care was taken artificially to increase the excitability, the question arose whether the brain might not after all, and in contradiction to the generally received opinion, possess a certain degree of electric excitability. Fritsch and Hitzig pursued the following method in their physiological investigations of this matter :—

Dogs were used, and at first not narcotised, but in the later experiments they were brought under the influence of anæsthesia. The skull was trephined, and then either the entire half of the skull-cap removed by forceps, or only that portion of it which covers the anterior lobes of the brain. In most cases, after one hemisphere had been used, the other half of the skull-cap was treated in the same manner. In all these cases, however, after on one occasion a dog had bled to death from a slight injury to the sinus longitudinalis, a bridge of bone protecting that sinus was left intact. The dura mater was then slightly incised, taken up, and completely removed down to the edge of the bone. This proceeding caused a good deal of pain to the animals, as shown by their screams and reflectory movements. At a later period, when the air had for some time had access to the parts, the dura mater became even more sensitive, which was carefully considered in all experiments. The *pia* mater, however, could be injured in all sorts of ways without causing any suffering.

As a rule a constant current of Daniell's (Siemens's) battery was used, which was just strong enough to excite a slight sensation of pricking and taste on the tongue. The faradic current was only used in a few experiments. A rheostat of 2,100 Siemens's units, a Du Bois-Reymonds key, and fine platinum electrodes, which were generally at a distance of from two to three millimètres, were employed.

The general result, deduced from a large number of experi-

ments, is that *one part of the convexity of the cerebrum in the dog is motor, and this is, generally speaking, situated anteriorly; while another part is not motor, and this is, generally speaking, situated posteriorly. By electric stimulation of the motor portion, combined muscular movements of the opposite side of the body are produced.*

If a very feeble current be used, these movements are localised in certain well-defined sets of muscles; but if the current employed be powerful, other sets of muscles, not only in the opposite, but also in the corresponding side of the body, are acted upon. The possibility of isolated stimulation of a well-defined set of muscles is limited to small parts, which may conveniently be called centres. A slight displacement of the electrodes caused motion of the same limb, but if there was at first extension, the displacement caused flexion or rotation. Those parts of the surface of the brain which are situated between the centres were unexcitable by a very feeble current. If the distance of one electrode from the other, or the power of the current, was increased, movements could be produced; but these contractions affected the whole body in such a manner as to make it difficult to distinguish whether they were unilateral or bilateral.

The locality of these centres is very constant in the dog. At first that portion was determined which caused the strongest contractions of a certain set of muscles, with the minimum power of current. A pin was then inserted between the two electrodes into the brain of the living animal, and after removal of the brain, the points thus marked were compared with previous specimens which had been preserved in spirits of wine. The situation of these centres is so constant, that Fritsch and Hitzig succeeded repeatedly in finding the intended centre, without otherwise opening the skull, in the middle of one head of a trephine. After the dura mater

had been removed, the muscles dependent upon such a centre could be made to contract as well as if the whole hemisphere had been laid bare.

The centre for the muscles of the neck is situated in the middle of the pre-frontal convolution, while the extreme end of the post-frontal convolution contains, next the end of the frontal fissure, the centre for the extensors and abductors of the fore-leg. Somewhat at the back of this, and nearer to the coronal fissure, are the centres for flexion and rotation. The centre for the hind-leg is likewise in the post-frontal convolution, but nearer to the middle and more to the back than that for the fore-leg. The portio-dura receives its motor influence from the middle portion of the super-sylvian convolution.

It was not possible in all cases to cause contraction of the muscles of the neck from the first-named centre. The muscles of the back, tail, and abdomen, were generally moved by stimulation of the parts mentioned; but a circumscribed point, from where they could be individually excited, could not be accurately defined. The whole portion of the convexity of the brain which lies behind the centre for the portio-dura, is absolutely unexcitable to even a powerful current.

The character of the contractions caused by stimulation of these motor centres differs according to the way in which they are stimulated. Making the current in the metallic circuit causes a single contraction, which disappears rapidly; but if the circuit be closed by simply putting the electrodes on, it is necessary to use a stronger current for producing the same effect.

It appears that the anode constantly preponderates, and that if the power used be minimal, this is the only electrode which will cause contractions. When the circuit has been closed for some time, voltaic alternatives increase the effect.

With tetanising induction currents, the results obtained are not so constant. Frequently there are some contractions of corresponding sets of muscles, and which diminish only after a considerable time. In other instances there is at once a maximum of contraction, after which no further effect is produced. Prof. Weber had already shown that after breaking a current which had tetanized the cord of a frog, movements occurred subsequently in all the muscles of the body. The same observation has now been made with regard to the cerebral substance, as subsequent movements occurred, even when the irritation had lasted only a few seconds; there being distinct tremor in the facial muscles, while the extremities were convulsed by clonic spasms. In two animals well-marked epileptic attacks came on subsequently. These began unilaterally with contractions in the muscles, which had been previously irritated. The pupils in these cases were intensely dilated.

It might be objected to these experiments that the results observed were owing to portions of the current travelling from the irritated parts to others at a distance; but if it be considered that always a very feeble current was used, that the cerebral substance offers a not inconsiderable resistance, and that the distance between the electrodes was very small, it would appear that the density of the current could only be minimal even near the point of irritation. Again, such derived currents would no doubt preferably affect the nerves of the same side of the body, there being no reason whatever why they should exclusively travel to those of the opposite side. Furthermore, the motor nerves of the eye are in the immediate neighbourhood of the irritated points, so that if a derivation of the current took place, the eye would be moved more readily than the fore- or hind-leg. There is, however, in the whole convexity not a single point, the irritation of which, even by a stronger

current than that which was generally used in these researches, ever caused movements of the eye.

One reason why similar phenomena have not been noticed by previous observers may be, that the excitability of the brain sinks very rapidly under such circumstances, and is indeed gone before death takes place.

Immediately after death it appears utterly lost, even if a most powerful current be used, while the muscles and peripheral nerves retain their excitability much longer. It is therefore necessary that circulation should still be active at the time such experiments are undertaken.

It does not appear probable that these contractions are owing to reflex action. Such action might, perhaps, be transmitted by the nerves of the dura and the pia mater; but this is, for various reasons, very doubtful. Fritsch and Hitzig believe that previous experimenters were unsuccessful in their investigations because they did not lay open the whole convexity. It appears, indeed, that the posterior and lateral wall of the skull-cap of dogs, beneath which there are no motor parts, is the portion easiest to trephine; and they probably commenced the operation there, without proceeding further to the front, thinking that the several portions of the surface had the same function.

Dr. Ferrier [1] has apparently come to similar conclusions as the two German observers, but has as yet only given a preliminary notice of his researches. He considers the anterior portions of the cerebral hemisphere the chief centres of voluntary motion; states that powerful irritation of one corpus striatum causes rigid pleurosthotonus, the flexors predominating over the extensors; that the corpora quadrigemina, besides being concerned with vision and the movements of the iris, are centres for the extensor muscles

[1] British Medical Journal, April 26, 1873.

of the head, trunk and legs; that the cerebellum is the co-ordinating centre for the muscles of the eyeball; and that nystagmus is an epileptiform affection of the cerebellar oculo-motorial centres.

Cerebral symptoms in the living man are most easily caused by directing the continuous current to the auriculo-maxillary fossa, the mastoid process, and the occipital region. This is partly owing to the circumstance that the epidermis in these places is fine and not covered with hair, which latter is a bad conductor even when moistened; and partly to certain vascular peculiarities existing in these parts. Thus we find that a large vein connecting the sinus transversus with the posterior auricular veins, and likewise the posterior meningeal artery, proceed through the mastoid foramen into the skull. Again, in the occipital region, there is a connexion between the sinus transversus and the vena cervicalis profunda, by means of a vein coursing through the posterior condyloid foramen.[1]

Galvanic giddiness.—That the continuous current, when directed through the head, will cause giddiness, was already known to Augustin,[2] who says that if a wire be coiled round the ears, moistened with salt water, and connected with the poles of the battery, giddiness is experienced and flashes of light are seen. Purkinje[3] observed that if the current was sent through the ears, it caused fulness of the head and a general feeling of dizziness, the direction of which was upwards from the right to the left side, if the negative pole was in the right, and the positive in the left ear; while with the reverse arrangement of the electrodes it proceeded upwards from the left to the right side.

In order to render the movements of the body which are

[1] Luschka, Anatomie des Menschen, vol. iii. 2. p. 154; and Ziemssen, *loc. cit.* p. 139.

[2] Geschichte der galvanischen Electricität, 1803, p. 129.

[3] Rust's Magazin für Chirurgie, 1827, vol. xxiii. p. 297.

produced under these circumstauces plainly perceptible, Immermann[1] fixed a camel-hair brush on the head, and arranged a carbonised plate horizontally above the head in such a manner that the brush portrayed on it the movements which occurred. It was then seen that the feeling of giddiness may be intense, and yet only a very slight displacement of the head towards the side may take place.

Brenner,[2] who has made a considerable number of experiments with Immermann's brush, found that the body is always inclined towards that side were the anode is applied. This tendency commences on making the current, increases during the first few seconds while the circuit is closed, and then diminishes. On breaking the current there is a short giddiness, in which the head is inclined towards the cathode. On reversing the direction of the current, the giddiness increases, and the body is inclined towards the opposite side. The greatest effect is produced by placing the electrodes in the auriculo-maxillary fossæ.

Hitzig,[3] who has more recently investigated this subject, found that some people were more easily affected than others. Patients suffering from locomotor ataxy were particularly sensitive in this respect. As soon as the current commences to flow, the perception of the condition of objects, or of one's own person, in space, is altered. If the current be transversely sent through the anterior or posterior part of the head, vertigo is not so easily caused ; but if one electrode be in the auriculo-maxillary fossa, and the other at an indifferent point, say in the hand, it is produced at once. Variations in the density of the current are likewise most effective, but it was not possible to determine whether the anode has more effect than the cathode, and opening more

[1] Deutsches Archiv, vol. i. p. 595.

[2] Untersuchungen und Beobachtungen, etc. Leipzig, 1868, vol. i. p. 75.

[3] Du Bois und Reichert's Archiv, 1871, p. 716.

than closing. The condition of the skin has a great influence upon the result. A slight abrasion, a more or less moist state of the cuticle, will considerably alter the phenomena. There is some difficulty connected with the appreciation of results, inasmuch as one has to rely upon the statements of the persons experimented upon, who may one day be more predisposed to experience giddiness than another. On the whole, however, it would appear as if the anode was more effective than the cathode. Vertigo is experienced during the whole time the current acts, provided the latter has a certain tension; and an alteration in the direction of the current increases the phenomena.

Hitzig has distinguished three different degrees of giddiness. The first and slightest may be called fulness in the head, and is produced by a feeble current. There is a degree of uncertainty as regards the position of one's own body or of external things in space, but no apparent or real movements of the body. It is only perceived on breaking the current, while making it, or the closed circuit, have no effect.

The second degree is characterised by apparent movements. The objects seem to turn while the current circulates, like a wheel placed parallel to the face, in a direction from the anode to the cathode. On breaking the current this direction is reversed, so that the apparent movement ascends from the cathode, and descends towards the anode.

The third degree is produced by a more powerful current. On making the current, the person experimented upon staggers, and the head or the whole body are turned towards the side corresponding to the anode, while on breaking they incline towards the side corresponding to the cathode. Apparent rotatory movements continue at the same time, and the rapidity of these imaginary movements increases in proportion to the power of the current.

If only one electrode be on the head and the other elsewhere, say in the supra-clavicular fossa, the head is inclined towards that side where the head-electrode is placed, while the objects seem to vanish towards the opposite side.

The same observer has found galvanisation of the head to produce *peculiar movements of the eyes*, provided the current is sufficiently strong to cause the second or third degree of vertigo. A current flowing transversely through the head, and alterations made in its direction, are most effective in this respect. These movements generally continue during the whole time the circuit remains closed, but gradually become less extensive; and if the current used be feeble, they may disappear altogether. They resemble nystagmus; at first there is a jerk towards one side, and this is followed by a somewhat slower movement towards the opposite side. If the power of the current be increased, the rhythm of these movements increases in rapidity, and at last the short jerk predominates, so that the eye is seen slightly oscillating, but almost fixed to the corner of the orbit. The sudden jerk occurs in the direction of the positive current. If the anode be in the right mastoid fossa, and the cathode in the left, both eyes are jerked towards the left, and are kept fixed there if the current be very strong.

It is not probable that these movements are owing to a direct transmission of the galvanic influence to the ocular muscles, because they take place more easily from the mastoid fossa than from the neighbourhood of the orbit; nor should they be attributed to stimulation of the motor nerves of the eye; it is more reasonable to assume that certain central portions of the brain respond in this manner to the current. Brenner has shown that if the anode be subdivided in two parts, and one part of it is put into each mastoid

fossa, while the cathode is placed to the nape of the neck, no vertigo is caused; but if one branch of the anode was removed, giddiness came on at once, even when the current used was less powerful than before. According to Hitzig, the same result occurs with regard to ocular movements. Even if the current be very powerful indeed, neither giddiness nor ocular movements occur, if both halves of the skull be acted upon by the same electrode; they only take place if the two contrary electrodes are used in this manner.

Hitzig has also found that if the ears of a rabbit be filled with moistened blotting-paper, and a galvanic current then sent through, the animal falls, on closing the circuit, towards the side of the anode, and the eyes are, with severe nystagmus, turned towards the side of the cathode. On opening the circuit, the reverse movements take place.

From all these observations it is quite evident that a continuous current of moderate power may be passed through the brain of the living man; and the only question which remains to consider in regard to this is, whether the current is exclusively transmitted to it in the way described by M. Erb (p. 71), viz. by way of the blood-vessels which penetrate from without into the cavity of the skull; or whether the reflex function of the fifth pair of cerebral nerves is likewise concerned in guiding the current to the brain, as I have always been inclined to assume.

An opportunity has lately been afforded to me of studying this question in the living subject, with due elimination of all sources of error; as I have been fortunate enough to observe, clinically, a case of complete anæsthesia of the entire fifth pair of cerebral nerves. In this patient, the reflex function of the trifacial nerve was completely excluded, and it appeared that no cerebral symptoms were produced, even if a current, which was powerful enough to cause intolerable sensations to a healthy person, was sent straight through the

head. The case alluded to appears to me to have a most important bearing on the settlement of this question, and I therefore subjoin the following particulars of it.

CASE I.—*Anæsthesia of the Fifth Pair of Cerebral Nerves.*

P. G., aged 27, unmarried, a sheep-farmer living in Australia, had been in good health until June 1866, when on riding across a vast plain in Queensland, and being much exposed to a keen wind blowing steadily into his face, he was suddenly seized with severe pain in the left side of the head, eyes, and face. At first, the sensation was as if the face were frost-bitten. The pain then became of a dull throbbing character, and continued so for five weeks. He put himself under the care of a local practitioner, who prescribed iodide of potassium and a blister. Some time after, on a similar exposure again taking place, the right side of the face became affected in the same manner, but the pain was not so severe, and the attack did not last so long as the first. When the pain was quite gone, the corneæ of both eyes became covered with thick opacities, and the patient completely lost his sight on the right side, while on the left he could still faintly distinguish light and objects at a short distance. The power of mastication also became completely lost, and the skin and mucous membranes of the face quite numb. He then went to Sydney, where he was admitted into the hospital, in which he remained five months. The surgeon under whose care he was there, ordered the eyes to be strapped up, probably with the intention of preventing perforation of the corneæ (Snellen). As time went on, some of the symptoms were rather improved, but as he was still incapacitated from doing any work, he came to England, and placed himself under my care.

I first saw the patient on April 21, 1868, when I found him in the following condition:

His intellect and memory were in no way impaired. He was able to fix his attention on subjects quite as well as previous to this affection; indeed, he complained much of the idleness caused by the loss of sight. This made him occasionally irritable and low-spirited. There was a peculiarly hard, almost statuesque expression of the features, which was due partly to a

slight œdematous effusion into the cellular tissue of the face, and partly to the complete loss of muscular sensibility.

On applying faradism by moistened conductors to the muscles of the face, these responded readily by contraction to the electric stimulus; but there was a complete absence of that peculiar sensation which in a healthy person always accompanies electro-muscular contractions, and which is caused by the stimulation of the sentient nerve-fibres which are distributed in the muscular substance. This latter was in no way affected, showing that the morbid influence had not reached the portio dura. All the varieties of physiognomical expression could be produced at will, but the effect made was more like that of an automaton than the natural appearance of sentient and animated features.

The sense of smell was quite normal, and had never been impaired. On applying a sufficiently powerful continuous galvanic current to the mucous membrane of the nose, a decided phosphorous smell was perceived by the patient.

Vision was obstructed by thick leucoma of both corneæ, but the optic nerve was not affected. Indeed, the patient was able not only to distinguish light and shade with both eyes, but he could also see near objects, and read single letters of No. 20 (8-line roman) of Jæger's test-types with the left eye, where the leucoma was not so thick as in the right. He was, however, quite unable to guide himself in the streets. He suffered a great deal from photophobia, and had to wear an eye-shade. This was a remarkable circumstance, as, in consequence of the leucoma of both corneæ, only very little light could penetrate to the retina.

Mr. Soelberg Wells was kind enough to make a careful opthalmoscopic examination of the fundus of the eye, and furnished me with the following report of the appearances noticed by him :—

'In both eyes the pupils became well dilated under atropine. In the right there are very delicate, threadlike adhesions between the edge of the pupil and the leucomatous portion of the cornea. In the left eye there are slight remnants of uveal pigment on the central portion of the anterior capsule, indicating that a slight iritis had formerly existed. The lens and vitreous humour are clear, and the background of the eye quite normal. In the right eye, on account of the dense central leucoma, the optic disc could be only imperfectly seen, but in the left eye it was quite visible.'

The motor nerves of the eye were in their normal condition, there being neither ptosis nor strabismus nor double vision, and all movements of the eye, upwards, downwards, and laterally, being easy of execution.

The pupils were rather constricted, and were only very slightly influenced by variations of light and shade.

In describing the condition of the fifth nerve, I shall speak,

1st. Of the skin of the face and scalp;

2nd. Of the mucous membranes of the eyes, nose, and mouth; and

3rd. Of the muscles of mastication.

1st. The common sensation of the face and scalp was entirely lost in both sides, the limit of the anæsthesia being vertically a line running one sixth part of an inch inwards from the horizontal and ascending branches of the lower jaw; and horizontally a line drawn from the tragus of one ear, right across the skull, to the tragus of the other ear. All the parts comprised between these lines, including the temples, forehead, nose, cheeks, and chin, had lost their sensibility. As regards the ear, the tragus was anæsthetic, and part of the external meatus benumbed, while the concha was perfectly sensible. In like manner, the skin of the back part of the skull, and the skin of the neck, had preserved their ordinary sensibility. In the anæsthetic parts of the face and scalp just alluded to, neither pricking nor pinching nor any other mechanical irritation was in the least degree perceived by the patient. Faradisation by dry conductors did not produce any sensation, even when a powerful current was used. On applying to the face the continuous current of ten cells of Daniell's battery, which deflected the needle of the galvanometer to an angle of thirty-five degrees, and which, in a healthy person experimented upon at the same time, caused not only a feeling of heat and pricking in those parts of the skin to which the electrodes were applied, but also a sensation of taste on the tongue, and a flash of light, chiefly on breaking the circuit, no physiological effect whatever was produced in the patient. On using a current of twenty cells of the same battery, which deflected the galvanometer to an angle of fifty degrees, and in a healthy person caused contractions of the muscles of the face, both at the entrance and the cessation of the current, together with strong pricking and heat, vivid flashes of light, giddiness, and strong galvanic taste, no sensation was produced in the patient, but the facial muscles responded readily, chiefly on

making the circuit. On further increasing the power of the current to thirty cells, which deflected the galvanometer to an angle of seventy-two degrees, and in a healthy person caused the perception of dazzling flashes of light, a hissing noise, a phosphorous smell, and such powerful feelings of heat, giddiness, and sickness as to be unbearable for more than a second, the patient perceived a slight sensation of warmth and pricking, a slight coppery taste, a slight phosphorous smell, and slight giddiness. These sensations had much the same degree of intensity wherever the poles were applied.

The sense of temperature was completely absent, for neither intense cold, as caused by the application of ether-spray or ice, nor heat, caused the least sensation. This had been so from the commencement of the affection; and the patient had several times, on lighting a pipe, accidentally scorched his face without being aware of it at the time.

The sense of touch was entirely gone; for neither of the two points of the æsthesiometer was perceived by the patient. Nor was the sense of locality preserved, for the patient could not tell where he was touched or pinched.

2nd. *The Mucous Membranes of the Eyes, Nose, and Mouth.*—*a.* The conjunctiva of both eye and eyelid was completely anæsthetic on both sides, and could be touched by the finger, and blunt and sharp instruments, without exciting reflex movements or lachrymation. The patient stated that when he washed his face he always kept the eyes open, and never felt the contact of either water or soap.

The secretion of the lachrymal gland appeared to have totally ceased; and the application of substances which generally excite a flow of tears, such as ammonia and mustard, had no such effect. There was, however, pathological hypersecretion of conjunctival mucus, by means of which the eye was kept moist. Indeed, the cornea appeared covered with streaks and shreds of mucus, which gave a death-like appearance to the eyes. This mucus was most probably secreted by the mucous follicles first described by Prof. Krause, and which are situated below the conjunctiva, where this membrane is reflected from the eyeball upon the eyelid.

b. The mucous membrane of the nose was quite insensible to the touch of blunt or sharp instruments, and no sneezing followed the application of snuff. There was, however, an abundant secretion of mucus, which had at one time been so

excessive that thick scabs were continually forming in the nose This mucus was of so acrid a nature that on running down to the lip it made the skin of the sulcus naso-labialis, and part of the lip beyond the sulcus on both sides, very sore, and caused the moustache to fall out there. Otherwise, the beard and hair were in perfect condition, from which it appears that the growth of hair is not under the direct influence of the fifth nerve. That part of the upper lip, where the acrid secretion from the nose used to run, was quite white, and looked like a scar from burning, or from the application of sulphuric acid. At one time the nose used to bleed readily when slightly touched, but it had not done so lately. The reaction of the nasal mucus was neutral.

c. The mucous membrane of the mouth was also completely anæsthetic, as far as the gums, the tongue, the inner surface of the cheeks, and the hard palate were concerned. The tongue presented a most frightful spectacle, having been severely bitten and lacerated in every direction during the act of taking food, the patient being entirely unconscious of his biting the tongue whenever he did so. Some parts of the inner surface of the cheeks had also been bitten, and were badly ulcerated. The secretion of buccal mucus was so excessive as to oblige the patient to have a pocket-handkerchief constantly applied to the mouth, in order to prevent the liquid from running down the chin. The lips appeared covered with a sort of froth, such as we see in a patient who has just come out of an epileptic attack. Both corners of the mouth were very sore, being macerated by the constant flow of mucus. The reaction of the liquid was slightly alkaline.

The insensibility of the gums was so complete, that on one occasion, when the patient had a tooth drawn, he felt nothing of the operation. The remaining teeth were perfectly healthy.

The sense of taste was not lost, for the patient tasted sugar, quinine, and salt on the front as well as on the back part of the tongue; yet in the anterior portion of the organ the perception of taste seemed to have lost its quickness, for while, on my applying sapid substances to the posterior part of it, the patient would at once exclaim 'sweet,' 'bitter,' 'salt,' he took about five or six seconds, on the front part of the tongue, to describe the taste, but he never made a single mistake there. He also perceived the galvanic taste of five cells of Daniell's battery, if directly applied to the tongue.

3rd. *The Muscles of Mastication.*—The muscles of mastication,

which are animated by the minor portion of the fifth nerve, had not escaped the pathological influence. At one time the temporal and masseter muscles, which move the jaw upwards, were completely paralysed, so that it dropped, as in a dead body, and the mouth was always open. Both pterygoid muscles being also completely paralysed, mastication was rendered impossible; and the patient never masticated the food he took for sixteen months consecutively. He was therefore obliged when taking solid food to have it minced, and then bolt it. Curiously enough, digestion had never suffered in consequence of the want of mastication, which I think must be explained by the circumstance that a thorough moistening and soaking of the food taken, with a slightly alkaline liquid, went on at least as copiously as it could have done before, through the pathological hyper-secretion of buccal mucus, to which I have already alluded, and which therefore, in this case, seemed to exercise a kind of compensating influence.

For several months previous to the patient's coming under my care, the voluntary power had gradually returned in the temporal and masseter muscles, so that the mouth could be closed, and the vertical movements of mastication were well carried out. The pterygoid muscles, however, remained paralysed, which rendered the lateral movements of the jaw impossible. He had also great difficulty in putting out his tongue.

Other muscles, animated by the minor portion of the trifacial nerve, are the mylohyoid, the digastricus anticus, the tensor palati mollis, and the tensor tympani. As regards the three first named, no morbid symptoms could be discovered showing that they were paralysed. The position and function of the soft palate were in no way altered, which is probably due to the circumstance that the tensor palati mollis receives nervous influence not only from the minor portion of the trifacial, but also from the pneumogastric and the accessory nerve.

The patient complained of a continuous rushing noise in the head, which he compared to that made by the paddle-wheel of a steam-boat. It would be difficult to say whether this symptom was due to paralysis of the motor fibres animating the tensor tympani muscle, or to anæsthesia of the sentient petrosus superficialis minor nerve, which proceeds from the ganglion oticum to the tympanic plexus of nerves.

The sense of hearing was perfectly normal.

The speech was rather thick and indistinct, in consequence of the lacerated condition of the tongue, but not from any affection of the hypoglossus nerve.

All the remaining parts of the nervous system were in good condition; nor was there any disorder of the chest, stomach, liver, bowels, skin, or genito-urinary organs.

There was no history of scrofula or syphilis.

Such being the condition of the patient, no real difficulty could be experienced in determining the nature and exact seat of the pathological lesion. The patient had evidently suffered from rheumatic inflammation of the neurilemma, first of the left, and afterwards of the right, trifacial nerve, where it emerges from between the transverse fibres of the pons Varolii at the base of the brain. This inflammation had resulted in effusion, and subsequent compression and atrophy of the nervous matter.

The affection had to be traced to the nerve-trunk at the base of the brain, and not to any more peripheral part, because not a single fibre of the trifacial nerve had escaped the injury. If the lesion had been more peripheral—for instance, if it had been confined to the Gasserian ganglion—the muscles of mastication would not have suffered. At the same time it was evident that the disease could not have spread to the pons Varolii, because there was an entire absence of all symptoms which occur in disease of the pons. The lesion was therefore confined to the course of the fifth nerve between the pons and the Gasserian ganglion. As the case did not end fatally it was impossible to verify the diagnosis by actual inspection, which however could have added but little to the pathology of the case.

The treatment consisted of the systematic application of the continuous galvanic current to the several branches of the fifth nerve, the anode being placed to the nape of the neck, while the cathode was passed along the peripheral ramifications of the nerve. No medicine was given.

After this treatment had been followed for about three months, with several interruptions due to extraneous circumstances, the following change had taken place in the patient's condition:— The symptom of photophobia had entirely disappeared. Indeed the patient was able to leave off wearing the eyeshade after the first few applications of the galvanic current. The tinnitus aurium was likewise almost entirely gone; it was only occasion-

ally slightly perceived when the patient was lying down at bedtime. The opacity of the cornea was considerably less on the left side. The patient could read No. 10 (pica) of Jäger's test-types with the left eye, while, when he first came to me, he could with great difficulty make out single letters of No. 20 (8-line Roman). On the right side the improvement was likewise satisfactory, as the patient could read single letters of No. 20 with that eye. When I first saw him he was obliged to be led by another person; but now he was able to guide himself in the streets, and to read the street names at the street corners and the signboards of shops. Common sensation had to a great extent returned in the left side of the forehead, the right cheek, and the chin. In the other parts of the face it was still considerably impaired. The sense of locality in both sides of the face was re-established, for the patient could tell distinctly where he was touched or pinched. The sense of temperature had come back to some extent, for the patient was able to distinguish between heat and cold, although not so keenly as previous to the affection. The sense of touch had returned in the left side of the forehead, the right cheek, and part of the chin, as shown by the proper perception of the two points of the æsthesiometer. The secretion of tears and saliva had partially returned, while the excessive secretion of mucus had been checked. The lips were no longer covered with froth, but quite dry. The lateral motion of the muscles of mastication was nearly re-established. The patient could now no longer bear thirty cells of the battery, which he said *made him feel drunk*; showing that the conduction of the current to the brain was favoured by the re-establishment, to some extent, of the reflex function of the fifth pair of nerves. The patient was, when last seen, able to follow a light occupation.

Without entering at present into all the points of interest in physiology and pathology upon which the case just related is apt to throw light, I will only make a few remarks on the curious fact of the absence of cerebral symptoms during the application of a powerful continuous current to the head. Indeed, it was only by increasing the power of the current to such a degree as to rouse the faint remnant of sensibility of the trifacial nerve that a slight feeling of giddiness was caused. Now, as the physical relations of the skull, brain,

and blood-vessels were in no way altered in this case, there ought to have been no alteration as regards the production of cerebral symptoms, if the current only followed the way of the blood-vessels; but as there was a decided diminution of cerebral reaction, it is satisfactorily proved that the transmission of the continuous galvanic current to the brain is effected not only physically, but also physiologically, by nervous action.

Ziemssen[1] has objected to my argument, that it had not been shown whether the galvanic response of the brain was improved simultaneously with the improvement of the sensibility of the trigeminal nerve. I had indeed, in my first description of this case, not laid sufficient stress upon that circumstance. From the foregoing, however, it will be seen that the *cerebral response was improved simultaneously with the function of the trifacial*; as after the patient had been under treatment for some time, he said that thirty cells of the battery, which at first had no effect at all, made him feel drunk, and that he could not bear the sensation. Ziemssen's objection, therefore, cannot be considered valid.

Although the induced current may penetrate to the brain, it seems to exert only little influence on it, just as on the retina and the other organs of special sense. If applied to the temples it causes pain and muscular contractions, but no giddiness or sensations of light, except in persons who are unusually sensitive to all forms of electricity.

II.—ACTION OF ELECTRICITY UPON THE SPINAL CORD.

The question whether faradisation or galvanisation of the spinal cord in animals produces movements of the corre-

[1] Die Elektricität in der Medicin, vierte Auflage, Berlin, 1872, p. 140.

sponding muscles of the extremities, has until lately been an open one. Some physiologists have attributed motor electric excitability to the anterior columns of the cord, while others have considered the contractions observed as owing to irritation of the posterior roots of the spinal nerves.

Prof. Weber,[1] who was the first to investigate this subject experimentally, found that when one electrode of an induction apparatus was directed to the upper, and the other one to the lower extremity of the cord, all the muscles of the trunk and of the extremities were thrown into tetanic convulsions. The same occurred if one electrode was placed to the anterior, and the other one to the posterior, surface of the upper portion of the cord; and likewise when both electrodes were applied to its lower portion, provided that the integrity of the organ had not been destroyed. Hence he concluded that the cord is the nervous centre for all the muscles of the trunk and the extremities; for if it were only the common trunk of all the motor nerves emerging from the vertebral canal, faradisation of the lower portion of the organ would only produce convulsions of the hind-legs, but not of all four extremities. When the cord was divided in the middle, and its lower half submitted to the faradic stimulus, only the muscles of the hind-legs were seen to enter into contraction; and if both parts of the cord were made to touch one another closely at those points where the section had been made, so that there could be no impediment to the passage of the current to the upper portion, the muscles of the upper extremities nevertheless remained perfectly quiet. From this Weber inferred that the convulsions described were not produced because the electric current was transmitted from the cord to the motor nerves, but because

[1] Loc. cit.

the passage of the current excited the action proper of the organ, which in its turn excited the property of the motor nerves to produce commotions of the muscles. He also observed that the tetanic convulsions produced in the extremities by the same means continued for some time, say half a minute, after the cessation of the current; while, if the anterior roots, or the mixed nerves were excited, the contractions disappeared immediately after the circuit had been broken.

Inhibitory effects.—Galvanisation of the spinal cord produces convulsions of the extremities on making the circuit of the voltaic battery; but if the current continue to traverse the cord, an inhibitory effect is caused, whatever may be the point to which the electrodes are directed. As long as the cord is traversed by the current, it remains insensible to a stimulus which may be applied to it. Thus we may prick the cord by a pin or excite it by an induced current, and the extremities will nevertheless remain quiet; but on breaking the circuit, mechanical or electrical excitation of the cord will again give rise to tetanic convulsions of the limbs. It was first pointed out by Baierlacher[1] that this diminution of excitability is confined to the spinal cord, and does not extend to the motor nerves and muscles; for if an induced current be applied to the motor nerves of the hind-legs, the cord being at the same time traversed by the continuous current, those muscles are seen to contract the nerves of which are submitted to faradisation. The inverse continuous current appears to have a more powerful inhibitory effect on the spinal cord than the direct current.

Onimus and Legros,[2] although agreeing with some of these conclusions, have come in the main to somewhat different results, especially as far as the *direction* of the current used

[1] Die Inductions-Elektricität. Nürnberg, 1857, p. 102.
[2] Mémoires de la Société de Biologie. Paris, mai 1868.

is concerned. They attribute inhibitory effects only to the direct or centrifugal current, and say that if the anode be placed to the upper, and the cathode to the lower portion of the cord, the hind-legs of frogs, rats, or guinea-pigs, may be irritated in any manner, yet no reflex action will take place as long as galvanisation of the cord is continued. Again, if the anode be directed to the upper portion of the cord, and the cathode to one of the hind-legs, no reflex contraction can be caused in the galvanised limb, although they may be brought about in the other hind-leg which is not galvanised. When galvanisation is discontinued, the reflex movements re-appear, but are not so powerful at first as they were before the experiment. The inverse or ascending current applied to the cord, on the contrary, generally causes a series of contractions in the hind-legs, and even *augments reflex action*. These contractions are all the stronger if the excitability of the sentient nerves and of the spinal centre be great; and they nearly cease when the sentient nerves, or the cord, have lost their excitability.

Van Deen, Schiff, and other physiologists, contend that the substance of the cord itself does not respond at all to the electric stimulus, and that if convulsions are observed in consequence of such an application, this is due to the propagation of the electricity to the posterior roots of the spinal nerves. Engelken and Fick, however, support Weber's assertions. Wislocky found that faradisation of the upper portion of the cord caused tetanic contractions of the lower extremities only if part of the current was diverted to the roots of the lower spinal nerves.

S. Mayer,[1] has observed that gentle faradisation of the cervical portion of the cord in frogs, which were highly excitable at the time, caused 'orderly movements' of the

[1] Pflüger's Archiv für Physiologie, 1869, Heft i. p. 166.

lower extremities; and these movements were more easily produced by faradisation of the posterior than of the anterior columns. The difference appeared more striking in the upper enlargement of the cord. After the posterior columns had been carefully removed, no further movements took place; but if the cord was divided into an anterior and posterior half, both of which were connected just above the origin of the sciatic nerve, faradisation of the posterior half was effective, and of the anterior half ineffective. The same power of current which caused movements if applied to the cord itself, produced them if applied to the posterior roots, or the brachial plexus. These observations would seem to point to the conclusion that the movements which have been observed after faradisation of the cord are only reflectory, and caused by the stimulation being transferred to the posterior roots. Fick,[1] in his latest publication, however, maintains his previous statement that the anterior columns of the cord are excitable to faradisation, although not to mechanical injury. In his experiments the posterior roots, and all parts directly connected with the same, were removed, so as to exclude reflex action altogether. S. Mayer having expressed the suspicion that parts of the posterior roots, including the reflectory portions of the cord, might yet have been present in Fick's experiments, and that the contractions seen by him were therefore ordinary reflex movements, Fick requested Von Recklinghausen[2] to make a microscopic examination of those portions of the cord which had been previously faradised, and given rise to movements; but no trace of fibres of the posterior roots could be discovered in them. The circumstance that mechanical injury does not cause such movements, is explained by Fick in the following manner:—The motor fibres of the anterior

[1] Pflüger's Archiv, 1873, p. 216.
[2] Ibidem, vol. ii. p. 416.

columns are not so immediately connected with the muscles as the peripheral motor fibres, since they are first connected with the ganglion cells of the grey matter, and only thence with the peripheral nerves. Before, therefore, the stimulus is transmitted to the anterior roots, it has become enfeebled by dispersion. Mechanical injury is a feeble stimulus when compared to faradisation, so that it cannot penetrate from the anterior columns to the muscles. Moreover Setschenow has proved that the anterior columns contain inhibitory fibres; so that any stimulus affecting the anterior columns must act not only on the motor, but also on the inhibitory fibres, and therefore inhibit to some extent its transmission to the peripheral nerves of the muscles.

Budge and Waller have observed that the pupil becomes dilated by faradisation of that portion of the cord which is situated between the seventh cervical and the sixth dorsal vertebræ; and they have therefore termed this territory the *cilio-spinal region.* From this part of the cord the excitation is transmitted to the cervical sympathetic nerve, which takes its rise from it, and which animates the radiating fibres of the iris (musculus dilatator). These fibres contract energetically, if the cervical sympathetic nerve be faradised, and counterbalance the action of the circular fibres of the iris (musculus constrictor); thus dilatation of the pupil is produced. After the section of the sympathetic nerve the pupil becomes constricted, as by such an operation the radiating fibres of the iris are paralysed, while the circular fibres remain in their normal connection with the nerves.

Budge [1] has discovered a similar centre in that portion of the spinal cord which corresponds to the fourth lumbar vertebra. By faradisation of the same, powerful contractions of the vasa deferentia, the bladder, and the lower

[1] Virchow's Archiv, 1859, p. 115.

portion of the rectum are caused. The same effects are produced by stimulating a small ganglion situated in the neighbourhood of the fifth lumbar vertebra, and which receives branches from the third and fourth lumbar nerves. This ganglion Budge has called the *genito-spinal ganglion.* The section of the sympathetic on one side does not altogether prevent the effects of faradisation of the ganglion of the same side, although it considerably diminishes them. That any effect at all is produced under these circumstances, is due to the faradic stimulus being propagated by means of the connecting branches between the nerves of both sides.

We have already seen (p. 73) that the spinal cord is traversed by portions of the galvanic current when this is applied externally to the spine. Apart from the purely experimental proof, however, we have pathological evidence for this in the progress of spinal disease under the influence of the constant current, and which will be described in the fifth chapter. Indications that the current penetrates to the cord itself are likewise furnished by the circumstance that not unfrequently sensations of tingling and heat are perceived in the legs and feet when the spine is galvanised, more especially when the cathode is placed to the lumbar vertebræ (Brenner). Contractions of the muscles animated by the sciatic nerve, may be caused by a similar arrangement, with the aid of voltaic alternatives.

III. ACTION OF ELECTRICITY UPON THE CERVICAL SYMPATHETIC NERVE.

1. *Experiments on Animals.*

a. Faradisation.—The first observations on the physiology of the sympathetic were made by Pourfour du Petit, in 1727; and the first electrical experiments on it by M. Biffi, of Milan, in 1846. The latter physiologist found that,

when the pupil had become constricted after section of the sympathetic, it became dilated on faradising the cephalic end of the nerve. Dupuy, Breschet, and Dr. John Reid, likewise contributed their mite to the elucidation of this subject; but all these experiments were only the feeble forerunners of the important researches of Claude Bernard,[1] who may be said to have laid the foundation of the physiology of the sympathetic, in 1852. Since then Waller, Budge, Schiff, Brown-Séquard, and many other physiologists, have added something to our stock of knowledge; yet, the attempt which has recently been made to deprive Bernard of the credit that really belongs to him alone as far as this subject is concerned, is not only extremely ungracious, but also entirely unsupported by the facts of the case.

Bernard has shown that section and faradisation of the cervical sympathetic have altogether contrary effects.

After section of the nerve, the muscles of the eye, the angle of the mouth, and the nostril, are contracted; the ear is kept erect; the quantity of blood in the ear and in the whole corresponding side of the head is notably increased; the arteries are fuller, and seem to beat with more power; the temperature is augmented, in some instances by 11° or 12° F.; sensibility is increased; after the death of the animal sensibility and reflex function last longer than on the other side; perspiration, lachrymation, and the secretion of cerumen are increased; the colour of the venous blood is changed; poisonous and other substances, which are deposited in equal quantities on both sides, in the subcutaneous cellular tissue of the face, or at the base of the ear, are more rapidly absorbed on that side where the section has

[1] Sur l'influence du nerf grand sympathique sur la chaleur animale, in Comptes rendus, etc., 29 mars 1852; also Comptes rendus de la Société de Biologie, octobre et novembre 1852; and Leçons sur la Physiologie, etc., 1858, vol. i. p. 469.

been made; rigor mortis appears later and lasts longer; putrefaction commences later, and the current proper of the muscles is stronger than the same current on the other side.

By faradising the nerve, all these phenomena are reversed; the pupil is dilated; the eyelids open; the eyeball protrudes; the blood-vessels contract; the quantity of blood is diminished; temperature and sensibility fall below the average; the conjunctiva and cornea are dry; the current proper of the muscles is very weak; the excitability of the motor and sentient nerves of the iris, and of the muscles, and the contractility of the arteries, disappear sooner after death than on the other side; and cadaveric rigidity and putrefaction commence sooner.

All the phenomena observed after section of the sympathetic are due to a *paralytic condition of the blood-vessels*, which is the direct consequence of the operation, and owing to which more blood passes through these vessels in a given space of time than before; hence an increase of the vital properties of the contractile tissues and the nerves. This condition is reversed by faradisation, which causes the blood-vessels to contract, and for the time neutralises the paralysis induced by section of the nerve. Claude Bernard has also shown that section and faradisation of the vaso-motor nerves of the extremities produce the same effects as section and faradisation of the cervical sympathetic.

Faradisation of the inferior cervical ganglion and its cardiac branches accelerates the pulse; while faradisation of the pneumogastric arrests the action of the heart.

Faradisation of the central end of the sympathetic has an effect on salivary secretion, which is in apparent opposition to its other effects. For while it causes, generally speaking, a contraction of the blood-vessels, and retards the secretion of the lachrymal and other glands, it causes a flow of saliva.

This is not nearly as copious as that which is seen after faradisation of the chorda tympani, the lingual and auriculo-temporal nerves; but it is nevertheless plainly perceptible. That it should occur in spite of the contraction of the blood-vessels, which is caused by the same proceeding, is accounted for by the circumstance that the effect takes place directly on the secreting cells, and not on the blood-vessels of the salivary glands; for if the condition of the blood-vessels had anything to do with it, the secretion should be arrested, not increased. An active proliferation of the gland-cells, however, takes place during the irritation of the nerve, and the saliva appears loaded with salivary corpuscles.

Prussak[1] has made some observations on the effects of faradisation of the sympathetic on the blood-vessels of the tympanum; and found that the arteries were at first constricted, but became dilated after the irritation had ceased; the veins were dilated during the irritation, probably because the arteries were emptied; and they became constricted afterwards. In these experiments he rendered the tympanum of the dog visible by trephining the mastoid portion of the temporal bone, and illuminating the interior by means of a reflector.

b. Galvanisation.—The effects of the continuous current upon the sympathetic, when exposed in animals, have been studied by Fieber, who found that when a current of from ten to twenty pairs of a battery was directed to it, contractions appeared in the interossei, or the muscles of the foreleg, or leg, on one or both sides, and which varied from a scarcely perceptible oscillation to violent choreic movements. It was generally necessary to continue the application for a few minutes, in order to produce them; and they

[1] Sächs. acad. Ber., 1868, p. 101.

mostly persisted for a short time afterwards. It is difficult to believe that these phenomena could be owing to isolated stimulation of the sympathetic; more likely they were owing to portions of the current being derived from the place of application and proceeding to the brachial plexus of nerves.

Onimus and Legros,[1] who have experimented with the continuous current upon the sympathetic in animals, have come to the conclusion that it has just the opposite effect of faradisation; for while faradisation contracts the blood-vessels, and lowers the temperature of the parts depending upon the same, *the continuous current augments circulation.* On galvanising the nerve which is laid bare in the neck of a healthy rabbit, for two minutes, by a current of from 10 to 14 Remak's cells, the temperature of the ear is half an hour afterwards found to be 74°· 3 on the side where nothing had been done, and 79° on the galvanised side; an hour afterwards the galvanised side is at 81°· 5, and the non-galvanised at 81°. Again, the blood-vessels of the ear of a rabbit were examined during the passage of both currents alternately; and through the sympathetic it was found that the faradic current contracted the arteries, while the continuous current dilated them, and caused considerable vascularity. This effect is not owing to electrolysis of the nerve, and subsequent paralysis of the vascular coats; for supposing the nerve had been destroyed, and true paralysis of the vaso-motor nerves had been induced, the temperature would have remained higher, while in fact, an hour after the experiment, the effect had almost entirely ceased.

They likewise found that, although faradisation contracted the blood-vessels, yet after a time this contraction ceased, and the arteries actually became larger than they

[1] Traité d'Électricité médicale, Paris, 1872, p. 177.

had been before the operation; at the same time the temperature, which had at first been lowered, rose above the normal standard. This increase of temperature they explain by a diminution of arterial contractility. The continuous current, on the other hand, renders circulation more active, and re-establishes it when it has been arrested.

According to the same observers, the direction of the current has a decisive influence on the production of these phenomena. This is shown by the following experiment:— The frog's web is microscopically examined during the action of the current, and it is seen that the direct or descending current does not contract the arterioles; on the contrary, the circulation is augmented; within a few moments the arteries have increased in bulk, and the whole network of capillaries is seen in great commotion. If now the direction of the current be reversed, so that it passes in the ascending direction, the arteries become constricted; less blood arrives; the globules pass on very quickly, but one by one, and after some time circulation, although not quite arrested, is much less active than it was before. If now the direct current be again employed, circulation is once more accelerated. The diameter of an arteriole, as measured by the micrometer, was 0·008 before the experiment; after galvanisation with a direct current, it became 0·015; and when the reverse current had acted, the artery was so constricted as to be only 0·004 millimètre in diameter.

Another experiment of Onimus and Legros, showing the effects of galvanisation, is the following:—

The cervical sympathetic is laid bare in a rabbit; the pressure of blood in the carotid is taken by the hæmodynamometer, and appears very feeble, the pulsations being scarcely perceptible. A direct current is then passed through the sympathetic, and the pressure of blood becomes augmented by two centimètres of mercury. It remains at this level, fluctuating between an

elevation of one to two centimètres, during the whole time the current continues to circulate. At the instant of breaking the current, a slight rise takes place; the pressure still remains for some time at the higher level, and then slowly falls. The inverse or ascending current causes at first an augmentation of pressure, but gradually this descends by $\frac{1}{2}$ centimètre, and remains at that lower level.

The effects of galvanisation on the tension of the veins is shown by the following experiment:—

The cervical sympathetic is divided in the rabbit at the right side. Forty-five minutes afterwards, the canula of the hæmodynamometer is introduced into the jugular vein. The venous tension appears to be feeble and fluctuates between 30 and 40 millimètres of water. Galvanisation of the nerve causes a rise of 10 to 15 millimètres. Each time that the current is broken, the tension falls, and rises again regularly when the circuit is re-established.

In a vigorous dog, the skull is trephined, and the sympathetic laid bare. On putting the positive electrode on the portion of the brain which is laid bare, the blood-vessels are constricted, and the brain is slightly depressed. On putting the anode on the sympathetic and the cathode on the brain, injection of the cerebral capillaries is observed, and the brain protrudes outside, through the opening of the skull.

Duchenne[1] has been led to entirely different results, and considers that in equivalent doses (?) the continuous and induced current have the same effect. He found that a constant currrent of 15 to 30 cells, traversing the sympathetic to an extent of 3 or 4 millimètres below the inferior ganglion, produced a feeble but plainly perceptible constriction of the blood-vessels, and discolouration of the same side, during the whole time of the experiment. If the sympathetic, however, had been previously strongly irritated, and if therefore its excitability was already more or less exhausted, the same continuous current produced no longer

[1] Examen critique des principales méthodes d'Électrisation. Paris, 1870.

constriction, but dilatation of the blood-vessels during the whole time of the experiment. An extremely feeble induced current caused feeble constriction of the vessels of the ear in the first half minute, but dilated them afterwards. The same experiment on the sympathetic of a rabbit which, an hour before, had been powerfully faradised for three minutes, but in which the ear had resumed its normal vascularisation, at once dilated the blood-vessels.

Seeing the discrepancy of results arrived at by these several observers, it appears to us most desirable that the influence of the continuous current upon the cervical sympathetic should be freshly investigated by competent and unbiassed experimental physiologists, with special regard to the dose of electricity employed, and to the direction of the current.

Experiments in man.—A large number of observations have been made on the effects of electricity, and more especially of the continuous current, upon the cervical sympathetic nerve in the living subject. Yet the question of 'galvanisation of the sympathetic' is still in an unsettled condition, which in our opinion is chiefly owing to the circumstance that *it is impossible to localise the current in this nerve in the living man.* The methods principally used are the following:—

a. One electrode is placed in the auriculo-maxillary fossa, and the other to the transverse process of the sixth or seventh cervical vertebra on the opposite side of the body. *By proceeding in this manner, not only the upper cervical ganglion is affected, but the spinal cord and the base of the brain likewise receive the galvanic influence.*

b. One electrode is placed in the auriculo-maxillary fossa, and the other at the manubrium sterni, at the inner edge of the sterno-mastoid muscle. *This mode of application affects not only the upper and lower cervical ganglion,*

but also the pneumogastric, the depressor nerve, the laryngeal, and the descending branch of the hypoglossus nerve.

c. One electrode is placed in the auriculo-maxillary fossa, and the other inside the cavity of the mouth, opposite to the articulation of the lower jaw (Gerhardt). This mode of proceeding would, *primâ facie*, be a most effective one for localising the current at least in the upper cervical ganglion of the sympathetic; but it has up to the present time not been sufficiently studied.

Some recent observers have expressed grave doubts as to whether the sympathetic can really be reached by the galvanic current. Thus, Dr. Clifford Allbutt[1] thinks it 'the very midsummer madness of reasoning' to believe that the sympathetic is reached by it, and that any good can be done by the proceeding generally known as 'galvanisation of the sympathetic.' His sketch of the extremes to which some fanatics have gone in this particular is very amusing; but he has not given a single reason why the cervical sympathetic should escape the galvanic influence, if the current be applied as mentioned above. Moreover, his entire argument is vitiated by his having failed to perceive the difference between a powerful faradic and a feeble galvanic current. Nobody who would give a really impartial attention to this question would expect that two such entirely different things should produce the same effect. We might as well think that sulphur would have the same action in the system as sulphuric acid. The triumphant manner, therefore, in which Dr. Allbutt draws attention to the fact that 'the ear does not get red' in consequence of galvanisation of the sympathetic, is apt to excite a smile. The same mistake has been made by Dr. Buzzard,[2] who speaks of 'the important

[1] British and Foreign Medico-Chirurgical Review, July 1871.
[2] The Practitioner, February 1873.

experiments of Brown-Séquard (*query*, Claude Bernard?) having shown that *galvanisation* of the sympathetic in the neck causes contraction in the walls of the arteries supplied by its branches;' and thinks that, as one of the ultimate branches of the carotid plexus, viz. the central artery of the retina, may be examined during life by the ophthalmoscope, we might expect to see some alteration in the size or colour of this branch, during the proceeding known as galvanisation of the sympathetic. This he failed to perceive in one case he examined, and is therefore inclined to doubt that the current reaches the superior cervical ganglion. Now, neither Brown-Séquard nor Claude Bernard have ever experimented with the continuous current on the sympathetic, but only used induction currents of high tension. The objections raised by Drs. Allbutt and Buzzard may therefore be altogether disregarded. Moreover the researches of Burckhardt and Ziemssen (p. 77) have experimentally settled the question, whether the continuous current penetrates to the cervical sympathetic, in the affirmative.

We now proceed to a description of the symptoms which are caused by the proceeding known as 'galvanisation of the sympathetic,' and which we believe to be owing to simultaneous stimulation of the sympathetic, the pneumogastric, the depressor nerve, the cord, and the base of the brain. Curiously enough, the point that it is impossible to localise the current in the cervical sympathetic in the living man, has been entirely overlooked by electro-therapeutists, although attention was drawn to this fact in a previous edition of this treatise. We are therefore pleased to find that Prof. Cyon,[1] of St. Petersburg, has recently added his testimony to this circumstance; yet even he has not, to our mode of thinking, sufficiently separated and, as it were, dis-

[1] Principes d'Électrothérapie, Paris, 1873, p. 201.

sected the symptoms which are observed. We shall therefore endeavour, in the following remarks, to refer as closely as possible the phenomena which follow 'galvanisation of the sympathetic,' to the specific nerve-tracts, to the stimulation of which they owe their origin.

The proceeding known as galvanisation of the sympathetic produces:—

1. A feeling of *sleepiness* and *drowsiness*, which commences soon after the circuit is closed, continues during the application, and for some time after the current has been broken. It is probable that this is owing to a direct action of the current on the vaso-motor nerves of the head, which are contained in the cervical sympathetic; but whether the effect is owing to the arterial tone in the sphere of the carotid artery, and the pressure of blood in the same, being reduced or increased, and whether therefore the symptom has to be ascribed to a certain degree of anæmia or hyperæmia of the brain, is at present impossible to decide. In patients suffering from cerebral disease this symptom is sometimes very marked, and continues for hours after the application.

The *ophthalmoscopic examination of the retinal vessels* has naturally suggested itself as a test for the condition of the brain under the influence of the proceeding; but the results arrived at by different observers are somewhat contradictory. Thus Prof. Hammond,[1] of New York, states that he saw a distinct contraction of the arteries of the retina when he examined that membrane with the ophthalmic mirror. On the other hand, Dr. Buzzard[2] observed no change whatever in the size or colour of the artery during the passage, or after the withdrawal, of the current. Dr. St.

[1] Journal of Psychological Medicine, April 1870, p. 249.

[2] Loc cit. p. 89.

John Rossa, of New York, who examined this matter in conjunction with Drs. Beard and Rockwell,[1] observed that the arteries increased in size, and more vessels were brought into view. Five minutes after the application was over, the size and number of the arteries had diminished. The secondary effect of the proceeding was, therefore, to produce anæmia of the retina, inasmuch as the vessels were less perceptible after, than they had been before, the application. This effect was more marked when the positive electrode was in the auriculo-maxillary fossa, than when the direction of the current was reversed. When a feebler current was used, Dr. Hackley noticed a slight enlargement of the veins, and no anæmia after the application. The same observer noticed that faradisation of the sympathetic caused at first no change at all, but after a time produced the same effects as galvanisation. Mild currents and short applications generally caused contraction, while strong currents and long applications caused dilatation. The temperament or condition of the individual appeared to have a considerable influence on the result. The whole subject, however, evidently requires a new and careful investigation on the part of practised ophthalmoscopists.

2. *Certain changes in the pupil.*—Gerhardt [2] states that by applying the electrodes as described above (p. 166 *c.*), he caused dilatation of the pupil in healthy and sick persons, with the continuous as well as the induced current. Eulenburg and Schmidt[3] have observed that, if the anode of from twenty to forty cells of Daniell's battery was applied to the manubrium sterni, and the cathode to the auriculo-maxillary fossa, there was at first a slight dilation of the pupil of the

[1] A Practical Treatise on the Medical and Surgical Uses of Electricity, New York, 1871, p. 276.

[2] Loc. cit. p. 200.

[3] Centralblatt für die medicinischen Wissenschaften, 1868. Nos. 21 and 23.

same side, after which the pupil gradually became constricted. Sometimes these phenomena did not appear on first closing the circuit, but only after it had been closed for half a minute or a minute, and was then broken and closed again; they also occurred afterwards, each time the circuit was again closed. In most cases the initial instantaneous dilatation of the pupil was so slight that it could not be observed with the unassisted eye, but only with the aid of Giraud-Teulon's pupilloscope, which allows us to notice any modifications of the size and distance of the dispersing circles in the retina by minimal alterations in the diameter of the pupil.

It is a singular contradiction that Gerhardt should *always* have observed dilatation, and that Eulenburg and Schmidt, who operated with a far more powerful current than is generally used, should have found that a pupilloscope is necessary to render dilatation perceptible. I have myself made a number of experiments on this question, which have yielded such diverse results that I have been unable to deduce a general law from them.

3. *An effect on the heart's action*, which is probably owing to the stimulation of the pneumogastric and the depressor nerve in conjunction with the sympathetic.

Eulenburg and Schmidt found that, when the current had acted for some time, the rate of pulsation was diminished. Where the action of the heart was normal, the pulse fell from four to fifteen beats in a minute; but in pathological conditions, where the pulse was accelerated, as in certain forms of heart disease, exophthalmic goître, &c., the fall was more considerable. This diminished rate of pulsation was accompanied by a decrease of tension and pressure in the carotids of both sides, and even in the radial arteries, which was perceptible to the finger. An examination by means of the sphygmograph gave more distinct results, showing that the curves of the carotid, as they appear in healthy persons,

were decidedly altered. The line of ascension became more slanting, and deviated more to the right side; the pointed summit disappeared completely, or almost completely, and instead of it a broad level was traced, which either proceeded in a horizontal plane or showed another more or less steep ascension.

The rate of pulsation is likewise diminished by symmetrical application of both electrodes to each superior cervical ganglion, and by galvanisation of the spine with a strong direct current of from forty to sixty cells, even in the lower dorsal zone. Faradisation of the skin causes at first acceleration, and afterwards retardation of the heart's action, with corresponding graphic alterations of the radial pulse.

Dr. Beard,[1] who has also made some sphygmographic observations on the pulse during and after galvanisation and faradisation of the cervical sympathetic, has come to the following conclusions :—Both currents when applied in such a way as to traverse the region of the neck in which the pneumogastric and cervical ganglia of the sympathetic are situated, markedly affect the pulse. This effect is chiefly shown in abruptness of the systole and the diastole, and in shortening of the interval between the cardiac impulse and the arterial impulse. In general it may be said that the force of the pulse is increased. Its rapidity may be either increased or diminished, according to the length of the application and the strength of the current. The effect of a general application of faradism all over the body was to prolong the systole and the interval between the cardiac and the arterial impulse. The abruptness in the systole that is so marked during and after faradisation through the neck, was not observed after general faradisation. These effects on the pulse gradually pass away, but are distinctly traceable for a number of minutes after the electrodes are removed.

[1] The Medical Record, New York, 1871, p. 457.

4. *A general feeling of warmth throughout the system*, sometimes accompanied with sensible perspiration. Meyer, who was one of the first to notice this symptom, found that the feeling of heat was chiefly marked in the arm of that side which corresponded to the auriculo-maxillary fossa acted upon; and that drops of sweat were sometimes seen to issue from the hand and fingers. These symptoms cannot be owing to the influence of the current on the cervical sympathetic, for this does not contain any nerves for the upper extremity; nor can the pneumogastric or the spinal cord be credited with their production; and we must therefore assume that they are produced by the influence of the current upon the depressor nerve. The phenomena just mentioned are, however, not nearly so constant as one might be led to believe after Meyer's description; for I have used the current hundreds of times in the same way, and only in one single case seen sensible perspiration in the fingers.

Our present views of this subject are, as will be seen from the foregoing, essentially unsettled, and will have to undergo considerable modifications in course of time. It will be principally necessary—

1st, to separate carefully the phenomena owing to the influence of the current upon the different nervous districts which are traversed by it;

2nd, to study more accurately the effects of different doses of the current, there being reason to believe that small doses have contrary effects to those of large doses of the same agent;

3rd, to observe the influence of more or less prolonged applications of the current, the time during which the application is continued being an important factor in the production and modification of the phenomena; and

4th, to give attention to the direction of the current, so as to test the correctness of Onimus and Legros' propo-

sition, that the direct and inverse current produce opposite effects.

The question what may be reasonably expected in therapeutics from galvanisation of the sympathetic, will be discussed in the third chapter.

IV.—ACTION OF ELECTRICITY UPON THE ORGANS OF SPECIAL SENSE.

All the different forms of electricity are capable of rousing the vital energy of the nerves of the organs of special sense; this effect, however, is chiefly peculiar to the continuous current, less so to frictional electricity, and least to induction currents. Of the latter, the magneto-faradic current has more effect on these organs, and especially upon the retina, than the volta-faradic current; which is probably due to the circumstance, that the variations of the former are not so sudden and considerable as those of the latter.

1. *Organ of Vision.*—Sparks taken from the common electrical machine, and applied to the eyes, produce luminous appearances, which are, however, not very distinct. The Leyden jar produces a more considerable effect. One of the earliest electro-physiological experiments is that made by Leroy,[1] who sent the shock from a jar through the body of a young man suffering from amaurosis. One wire was put round the head, and another round the right leg, and the ends of these wires were then connected with the outer and inner coating of the jar. With each discharge the patient saw a flame passing before his eyes, and heard a loud report like that of a gun. If the shock was sent straight through the head of the blind man by means of one metal plate being fixed on the forehead and another on the back of the head, through which the jar was then discharged, the patient

[1] Mémoires de mathématique de l'Académie de France, 1755, p. 86.

had hallucinations, saw crowds of people, &c. It is singular that no serious mischief should have been done by such a brutal mode of experimenting.

The electricity of the electrophorus machine, if of somewhat high tension, causes a continuous perception of a bluish-white light, together with pain, and spasmodic contractions of the muscles of the jaw.[1]

If the current of a single galvanic pair be caused to act upon the optic nerve, one of the metals being placed to the conjunctiva or to the well-moistened eyelid, and the other metal to the other eye or eyelid, a faint flash of light is perceived at the commencement of the current; while the circuit is closed, luminous appearances are only seen by persons whose retina is highly sensitive; but there is again a distinct flash when the circuit is broken. This is, of course, no real development of light, but the flash is only seen by the person subjected to the experiment, in consequence of the vital energy of the optic nerve being roused by galvanism.

That the continuous current has a special influence upon the optic nerve, was discovered by Volta about 1800; and the phenomena connected with it were studied by Ritter, Purkinje, Joh. Müller, and Ruete. It cannot, however, be said that the subject was much advanced by the researches of these physiologists, inasmuch as all of them, carried away by their scientific enthusiasm, experimented upon their own eyes so repeatedly, and in such a very decided manner, as to cause a more or less considerable degree of hyperæsthesia of the retina, which was of course highly unfavourable to a correct appreciation of the appearances produced. Purkinje's[2] observations on this point read more like the dreams of a visionary than the investigations of a man of science; and Joh. Müller[3] nearly blinded himself by his experiments, so

[1] Schwanda, loc. cit.

[2] Beobachtungen und Versuche zur Physiologie der Sinne. Prag, 1819.

[3] Zur vergleichenden Physiologie des Gerichtssinnes. Leipzig, 1826.

that he had to rest his eyes for a considerable period in order to regain the vigour of his sight.

Helmholtz's observations[1] are the clearest and simplest which have been made on this subject, and constitue a real advance in electro-physiology. He experimented with a few cells of Daniell's battery, and found that if a feeble *inverse* current be sent through the optic nerve, the positive electrode being held in the hand, and the negative applied to the forehead, the dark visual field of the closed eye became lighter than it was before, and assumed a whitish-violet colour. In the lighted-up field, the entrance of the optic nerve appeared within the first few moments as a dark circular disc. This brightening, however, quickly diminished, and disappeared altogether on breaking the current. If this was done very slowly, no flash was seen. After the current had ceased to act, the visual field became darkened, and a yellow-reddish coloration was assumed by the light appertaining to the retina.

If the *direct* current was used, so that the positive pole was on the forehead, and the negative held in the hand, the visual field, which was only filled with the light appertaining to the retina, became on the whole darker than it was before, and assumed a yellow-reddish hue. Only the point of entrance of the optic nerve was seen well defined, as a bright blue circular disc on the dark ground; and of this disc sometimes only that half appeared which was turned towards the centre of the field of vision. On breaking the circuit, the field cleared up again, and assumed a bluish-white colour, and the entrance of the optic nerve appeared dark.

The circumstance that the field should become darkened by the direct current, shows that the voltaic current produces not only irritation, but also alteration of excitability.

[1] Handbuch der physiologischen Optik, Leipzig, 1867, p. 204.

As we shall see further on, Pflüger [1] has shown that a weak current increases the excitability of the nerve at the point towards which positive electricity is travelling (catelectrotonus), and diminishes it at the point from where positive electricity is arriving (anelectrotonus). According to this law, excitability would be increased with the inverse current at the cerebral end of the optic nerve, and diminished at the retinal end of it, while the opposite would take place with the direct current. The diminution and increase of the light appertaining to the retina could thus be explained, according to Pflüger's law, by assuming an effect produced on the cerebral end of the optic nerve. Thus one would expect that the inverse current should increase, and the direct current diminish, the light appertaining to the retina itself. With this view, a remark made long ago by Ritter [2] seems to coincide, who says that while the direct current continues to act, external objects become less distinct, and that they become more distinct again with the inverse current.

Helmholtz considers these phenomena as owing to electrotonus of the radiar fibres of the retina, combined with a constant feeble internal stimulation at the posterior portion of the retina. If the current be directed to the retina by putting the cathode to the nape of the neck, and the anode to the well-moistened eyelid, near the external angle of the eye, the field of vision appears dark towards the nose, and bright towards the temple; and the point of entrance of the optic nerve, which coincides with the bright portion, appears dark. If now the eye be so turned that the fixed point is just at the limit between the bright and dark portions, there proceeds from it a bright tuft of light towards the dark portion, and a dark tuft towards the bright

[1] Untersuchungen über die Physiologie des Electrotonus. Berlin, 1859.

[2] Beiträge zur näheren Kenntniss des Galvanismus. Weimar, 1805, Bd. II. pp. 159, 166.

portion of the field. These two ovally-contoured tufts cover nearly the extent of the macula lutea. On reversing the direction of the current, the bright and the dark of the whole phenomenon are likewise reversed.

The following would be the rationale of these appearances:—When the positive current enters at the external angle of the eye into the eye-ball, and leaves it at its internal and posterior part, the excitability of the retina is diminished at the latter and increased at the former; so that the inner half of the field of vision appears dark, and the external half bright. The optic nerve probably acts as a bad conductor, and enfeebles the current where it enters, so that the phenomena there are reversed. The fibres on the temporal side of the retina are traversed by the current in a direction towards the rods and cones, and those on the nasal side of the retina in a direction away from the latter. In the former there is, therefore, increased, and in the latter diminished, excitability.

Brenner[1] has more recently investigated these phenomena, and come to the conclusion that the galvanic current is directly propagated to the optic nerve, and that the excitability of the latter, as well as the quality of its response, varies considerably in different individuals. The response occurs most readily if the two electrodes be at a different distance from the optic nerve, provided this is neither very great nor very small. The duration and intensity of the response is greater if the direction of the line connecting the two electrodes approximates the longitudinal axis of the optic nerve; and one of the most favourable arrangements is that one, where one electrode is directed to the eye and the other to the nape of the neck. The colour of the light varies in different persons, but is always the same in the

[1] Untersuchungen und Beobachtungen, etc. Leipzig, 1868.

same person. Each pole produces its own colour, and that colour is always seen which corresponds to the electrode which is nearest to the eye. The colours vary from yellow to lilac, red, blue, and pink. On closing the circuit, the light appears to assume two colours, the one in the centre being the more intense of the two, lasting longer, and being produced by a comparatively more feeble current; while the one in the periphery forms a sort of pale area around the central light, disappears more rapidly, and requires a stronger current for its production. That colour which is the central one with the anode, is the peripheral one with the cathode, and *vice versâ*. The light diminishes steadily when the circuit is closed, and at last disappears entirely. On breaking the current, there is a momentary image in which the colours, as they were seen on making it, appear reversed.

It was formerly believed that the luminous appearances just described were produced by reflex action from the sentient fibres of the trifacial nerve to the retina; and this view was rendered plausible by the circumstance that they may be perceived, whatever be the position of the electrodes, provided that one of them touches a point of the skin or mucous membrane animated by a filament of the fifth pair. It is, indeed, not necessary to touch one or both eyes or eyelids; for flashes may be perceived by directing one electrode to the nose, and the other to the tongue, or by putting one into the mouth and the other into the rectum. The researches of Ziemssen, however, on the conductivity of the eyes (p. 76), render it highly probable that the phenomena described are owing to a direct transmission of the current to the eyes, which on account of the large proportion of water they contain, are one of the best conducting organs of the body.

The flash becomes more distinct and of a stronger colour on darkening the room, and Humboldt relates that, during

storms, the effect of galvanism upon the eyes is very much increased. Fowler made the experiment on himself at a time when one of his eyes was inflamed, and noticed that the flash produced in the inflamed eye was more brilliant than in the healthy one. On the other hand, Humboldt states that when he suffered from a bad cold, he was not able to perceive the flash at all, even if he made use of an otherwise most effective arrangement of the metals.

The intensity of the flash is directly proportional to the intensity of the current employed, and inversely proportional to the resistance offered to the passage of the current. A flash may be produced by a very feeble current, such as is generated by the contact of a half-crown piece and a penny; it is more distinct if, instead of copper and silver, tinfoil and silver, or zinc and gold, are used. A pile, consisting of a large number of pairs, may excite the retina in a violent manner, and instantaneous blindness may ensue from it. Duchenne, who was unacquainted with the influence of the continuous current on the retina, relates a case which fully proves the great importance to the medical practitioner of an accurate acquaintance with the physiological effects which electricity will invariably produce. He electrified a patient suffering from paralysis of the portio dura, at first with the induced current, and afterwards with the continuous current of a pile. Immediately after the electrodes of the latter had been applied to the face, the patient exclaimed that he saw the whole room in a blaze; he afterwards complained of having lost his sight on that side where the electrodes had been applied: and he never regained it. Duchenne, curiously enough, claims for himself the discovery of this

[1] Experiments and Observations relative to the Influence lately discovered by M. Galvani, and commonly called Animal Electricity. By Richard Fowler. Edinburgh, 1793.

[2] Versuche über die gereizte Muskel- und Nervenfaser. Von Alexander von Humboldt. Posen und Berlin, 1797, vol. i. p. 334.

special action of galvanism on the retina; but I have already mentioned that it was known to Volta before the commencement of the present century.

If the resistance to the passage of the current be great, the flash perceived in consequence of the galvanic excitation of the retina is very feeble. Thus, if the two metals are applied to the face at two points where the skin is dry, the flash is less vivid than if the skin be previously moistened. The flash is stronger if the electrodes be directed to the conjunctiva, or to the Schneiderian membrane, or to the mucous membrane of the mouth, than if applied to the skin of the face; since the delicate epithelium of the mucous membranes offers less resistance to the passage of the current than the epidermis.

Faradisation has much less effect on the retina than galvanisation. The extra current of a volta-faradic machine, which circulates in a short and thick wire, and has therefore a low tension, has no such effect at all; but the current induced in a long and fine wire has a slight effect on the retina. Magneto-electricity affects the optic nerve more than electro-magnetism, but not nearly as much as the continuous current. In accordance with physical circumstances, it is observed that faradisation does not produce a continuous sensation of light, but a more or less rapid succession of slight blue flashes, which produce a sort of glimmering, similar to that which is observed in certain forms of hyperæsthesia of the retina.

2. *Organ of Smell.*—Near the electrical machine, when in action, a peculiar smell is perceived which is half sulphurous and half phosphoric. This odour was formerly believed to be due to a peculiar state of the olfactory nerve caused by electricity, but it is now well-known that it arises from the development of ozone (p. 4).

Neither the common electric sparks, nor the electricity of

the electrophorus machine, nor electro-magnetism, nor magneto-electricity will cause a peculiar smell when applied to the mucous membrane of the nose. By directing these stimulants to the Schneiderian membrane, nothing but a more or less disagreeable sensation of scratching and tickling is produced, which is owing to electric irritation of the sentient branches of the trifacial nerve, with which this membrane is richly endowed; and sneezing not unfrequently follows such an application.

The continuous current is the only kind of electricity which is capable of rousing the vital energy of the olfactory nerve. But in order to effect this, a current of high tension is required, such as one cannot bear much longer than a few seconds, on account of the concomitant symptoms of dazzling flashes of light, giddiness, and faintness which it induces. The case which has been related above (p. 145) shows that when the function of the fifth pair is in abeyance, the peculiar smell, caused by the galvanic stimulation of the olfactory nerve, is perceived without being accompanied by any inconvenience.

Ritter[1] has experimented upon his own Schneiderian membrane with the current of a voltaic pile of twenty pairs, and says that the inconvenience caused to him by the experiment was 'awful.' He states that he noticed a peculiar smell, at the commencement of the current, while the circuit remained closed, on opening the circuit, and for some time afterwards. The effects differed somewhat according to the direction of the current. If this was inverse, he observed on making the current, and while the circuit was closed, an acid smell and loss of the capability of sneezing; at the cessation of the current, and a short time after it had been broken, the smell was ammoniacal, and there was disposition to

[1] Beiträge zur näheren Kenntniss des Galvanismus. Weimar, 1805.

sneezing. If, on the other hand, the direct current was used instead of the inverse, the contrary occurred, viz. ammoniacal smell and disposition to sneezing on closing the circuit, and while the current continued to pass; and an acid smell and loss of the capability of sneezing on opening the circuit, and a short time after it had been opened.

I regret that I have not been able to verify Ritter's observations in any single particular. The condition of the brain during the passage of such a powerful current as is necessary for affecting the olfactory nerve, is not favourable to accurate observations; but I certainly never felt, during that time, either disposition to sneezing or that peculiar sensation which is constituted by 'loss of the capability of sneezing.' The smell was neither ammoniacal nor acid, but phosphorous, and, as far as I have been able to judge, there was no difference whether the current was direct or inverse. The patient whose case is described on p. 145 never sneezed during the application of the current to the nose, nor did he feel any inclination to, or aversion from, sneezing; and his statement on the nature of the smell was that it was something like sulphur or phosphorus.

3. *Organ of Hearing.*—All forms of electricity are able to rouse the vital energy of the auditory nerve, which responds to the stimulus by sounds. The best way to make the experiment is to fill the external opening of the ear with water, or with a moistened compress of lint or chamois-leather, and to place an insulated sound with a metallic top, and connected with one of the poles of the battery, or induction apparatus, into the liquid or on the compress, the circuit being closed by another moistened conductor which is held to the nape of the neck.

The continuous current produces sounds, not only at its commencement but also while the circuit remains closed

and on opening it. Volta[1] relates, in a letter to Sir Joseph Banks, that when he introduced the poles of a pile of from thirty to forty pairs into the external meatus, he felt a shock to his head, and some moments afterwards heard a sound, or rather a noise, like scratching and bubbling, or like that of a viscid substance boiling. This noise continued without interruption, and became stronger, until the circuit was opened. A variety of sounds may, however, be produced by means of a much feebler current, such as is produced by a battery of three or four pairs.

Ritter was the first who endeavoured to distinguish the pitch of the tone produced by the galvanic excitation of the auditory nerve. He states that, when both his ears were enclosed in the circuit, he felt at the commencement of the direct current a strong shock, and heard the sound $\bar{g}$. This persisted as long as the current continued to circulate; on increasing its intensity, the sound became higher than $\bar{g}$. On the contrary, when the inverse current was used, the sound was lower than $\bar{g}$, and continued to become lower in proportion as the intensity was increased. Both sound and shock were weak on opening the circuit, whether the current was direct or inverse.

I have made a number of experiments with all sorts and directions of currents, and compared the sound produced by the galvanic and faradic excitation of the auditory nerve with that given by a tuning-fork of the present Philharmonic pitch; and I have always found the sound produced by electricity as near as possible to $\bar{a}$. I have never observed that by changing the direction of the current, or by increasing its intensity, the *pitch* of the sound was changed; the only difference I could perceive was in the *intensity* of the tone. It was louder if the cathode was directed to the ear,

[1] Philosophical Transactions, 1800, p. 423.

and the anode to the nape of the neck, than if the position of the electrodes was reversed. The tone was hardly perceptible with a current of low tension, and very loud if this was high; but the pitch invariably remained the same.

When the current used is powerful, the auditory nerve responds to it, even if one of the poles of the battery is not in the external meatus; and it suffices to touch with the electrodes any part of the face or head animated by the fifth pair of cerebral nerves. On applying a current of forty cells of Daniell's battery, by means of moistened conductors, to both cheeks, I not only perceive sensations of giddiness, pricking, heat, taste, smell, and flashes of light, but I also hear a distinct hissing sound, resembling the gushing of the wind through the rigging of a ship. Whether the effect of the current on the organ of hearing takes place by reflex action from the peripheral branches of the trifacial to the auditory nerve, or by direct transmission to the organ of hearing, is not yet determined.

Dr. Brenner,[1] of St. Petersburg, has made a most extensive series of researches on the action of electricity upon the auditory nerve. According to him the induced current is almost useless for experiments of this kind, because the rapidity with which the shocks succeed each other produces very unpleasant effects on the nerves of common sensation, without acting upon the nerve of special sense. A specific response of the auditory nerve may nevertheless be obtained, but only by single closing or opening shocks from the induction apparatus, the opening shocks being the more effective ones. The most convenient form of electricity for acting on the auditory nerve, however, is, according to him, the continuous current, not only because it is more

[1] Untersuchungen und Beobachtungen über die Wirkung elektrischer Ströme auf das Gehörorgan im gesunden und kranken Zustande. Leipzig, 1868. And a number of papers in different periodicals from 1863 to 1872.

certain in its effects, but also because the different responses of the nerve on closing the circuit, during the time it remains closed, and on opening it, may be separately studied; while the induced current, which has only an instantaneous duration, offers insuperable obstacles to the true appreciation of the phenomena separately. The best mode of experimentation is, to direct one electrode to the external meatus, while the other one is placed to any other part of the body. It matters not to which part this latter is directed, for the phenomena observed always remain the same, if only the same electrode is in the external meatus.

The following is the normal reaction of the auditory nerve: at the *cathode* the nerve responds with sounds on *closing* the circuit, and during part of the closed circuit; while at the *anode* the nerve answers only on *opening* the circuit. If a current of such strength be used as is proper for physiological and therapeutical experiments, there is no response at the anode when the circuit is closed and while the current continues to pass, nor at the cathode when the circuit is opened. On increasing the power of the current, the response at the cathode on closing appears first, and the nerve answers somewhat later on opening at the anode; on the other hand, if the power of the current be diminished, the effect at the anode on opening disappears sooner than the one at the cathode on closing.

Brenner's formula is expressed in symbols as follows:—

CaMaS = Cathode, making, sound.

CaClS 7 = Cathode, closed circuit, sound gradually vanishing.

CaBr0 = Cathode, breaking, nothing.

AnMa0 = Anode, making, nothing.

AnCl0 = Anode, closed circuit, nothing.

AnBrs = Anode, breaking, feeble and short sound.

The response at the cathode, on closing, appears at once

in its full intensity, and gradually diminishes as the current continues to act; while the response at the anode on opening is only noticed after the current has acted for a certain length of time; and, if the circuit be opened soon after it has been closed, the response at the anode on opening may sometimes be entirely wanting. If the direction of the current be changed so that the anode is replaced by the cathode, sounds may be produced with a much weaker current, which would not produce any sound at the cathode, on first closing the circuit; the reason for this being, that, after the circuit has been opened at the anode, the nerve is in a condition of increased excitability. This condition continues for some time after the opening at the cathode, so that, if the circuit be repeatedly closed at the cathode within a certain period, stronger sounds are produced than at first; or, which amounts to the same thing, a less considerable galvanic power is sufficient for producing the specific response of the nerve, on repeatedly closing at the cathode, than was previously required.

It is, however, not only the variations in the density of the current from its maximum to zero which cause sounds, but a response occurs likewise in consequence of variations during the continuous passage of the current. This obeys the same law as above, inasmuch as a variation of increase will cause the effect on closing, the cathode being in the meatus; and a variation of decrease will produce the response on opening, the anode being in the meatus.

The degree of response of the auditory nerve is not only affected by the absolute amount of the variations of the current, but also by the distance at which they are from zero; and, with a current that is at all effective, it will be found that the less powerful the original force of the current was, the slighter may be the variations which will induce a response of the nerve.

The sounds caused by the galvanic excitation of the auditory nerve vary in kind and intensity, according to the peculiarity of the person experimented upon, and according to the intensity of the current. They are described as humming, hissing, rolling, whistling, ringing, &c. The last named sensation is the one most frequently experienced, and when in its full development becomes a clear tone, the pitch of which may be musically determined, and which varies in different persons. Some people perceive, when the power of the current is increased, a regular scale of auditive sensations, proceeding from 'humming' through all the varieties mentioned above to 'ringing,' and who hear 'sounds' with low power, but 'tones' with high power.

An increase of the intensity of the current raises the pitch when the auditory nerve is under the influence of the cathode, and lowers it when the nerve is under the influence of the anode.

Brenner's publications have given rise to an animated discussion, which was commenced by Dr. Schwartze,[1] of Halle, who pronounced Brenner's statements to be altogether erroneous, and utterly devoid of value in a diagnostic, prognostic, and therapeutical point of view. He was answered by Dr. Hagen,[2] of Leipzig, who confirmed Brenner's statements in almost every particular; and by Brenner himself,[3] who contended that Schwartze's 'experiments of control' had been made without any regard to the mode of experimentation recommended by himself, and were therefore worthless. Dr. Sycyanco,[4] of Cracow, has come to the conclusion that the continuous current produces no response of the auditory nerve at all, neither on opening nor on closing the circuit, and neither at the anode nor at the cathode!

[1] Archiv der Ohrenheilkunde, 1865, Bd. i. Heft 1.
[2] Electro-otiatrische Studien. Leipzig, 1866.
[3] Virchow's Archiv, 1867, Bd. xxxi.
[4] Deutsches Archiv, etc., von Ziemssen und Zenker, 1867, Bd. iii. Heft 6.

Erb and Poorten have lately entered the lists for Brenner, and Benedict, Wreden, and Cyon against him. But the subject is not of sufficient importance for us to describe all the phases of this tedious controversy. Wreden[1] has endeavoured to prove that the acoustic phenomena produced by galvanisation depend upon a displacement of the ossicles of the ear, which is caused by contraction of the internal muscle of the hammer, or the stapedius. If this view were ultimately confirmed, it would be shown that the galvano-acoustic phenomena are owing to the current acting, not upon the auditory nerve, but upon the portio dura. At the present time, however, the passion which has been singularly enough imported into this, to most men, somewhat dry subject, renders any reconciliation between the actual combatants impossible, and we must therefore wait for further researches on the part of unbiassed observers before proposing any definite views on this subject for the acceptance of the profession.

The action of faradism upon the membrana tympani presents some differences according to the tension of the electricity used, and the greater or less velocity with which the shocks succeed each other. A single shock from an induction apparatus produces a noise like a scratch; if the currents succeed each other rapidly, the noises do so likewise, and then resemble the buzzing of a fly on a window, or the blowing of a distant trumpet. At the same time a sensation of pricking and pain is perceived, if the current be of high tension. The negative pole is more effective in the production of the acoustic phenomena than the positive.

By faradisation of the membrana tympani in the living man two other phenomena are produced, viz. a slight and unpleasant metallic taste, and a more or less abundant flow

[1] Petersburger Medicin. Zeitschrift, 1870, p. 526.

of saliva. The former of these has been noticed by Duchenne[1] and Baierlacher;[2] the latter was discovered by myself in 1858.

The production of the peculiar sensation of taste which is caused by faradisation of the drum of the ear, is due to stimulation of the trunk of the chorda tympani, which, after having emerged from the cavity of the tympanum through the fissura Glaseri, descends towards the lingual nerve, in the sheath of which it enters, and then proceeds towards the tongue. It is therefore proved by electro-physiological observations that the chorda tympani contributes to the perception of taste; and clinical experience has confirmed this fact; since in certain cases of paralysis of the portio dura, loss or diminution of taste has been observed, together with palsy of the muscles of the face; this loss of taste exists only on the affected side, and usually disappears at the same time with the other symptoms of paralysis of the portio dura. Several cases of this kind have been recorded by Sir William Gull[3] and others.

A not less interesting phenomenon is the flow of saliva produced by galvanisation and faradisation of the drum of the ear. My attention was directed to this fact in the following way:—Having often used electricity in patients suffering from nervous deafness, I noticed that during the operation movements of deglutition occurred. I then experimented on myself, with the view of ascertaining the cause of these movements, and found that, if a current of somewhat high tension was caused to act upon the chorda tympani, the saliva began to flow more or less abundantly; the effect being more marked with the continuous than with

[1] De l'Électrisation localisée et de son application à la physiologie, à la pathologie et la thérapeutique. Paris, 1855, p. 809.

[2] Die Inductions-Elektricität. Nürnberg, 1857, p. 98.

[3] A further report on the value of electricity as a remedial agent, in Guy's Hospital Reports, 1852, vol. viii. part i. p. 81.

the induced current. This effect is due to electric stimulation of those fibres of the chorda which do not proceed towards the tongue with the lingual nerve, but are detached from its principal portion, and penetrate into the submaxillary ganglion. The saliva, therefore, which is observed to flow when the chorda tympani is electrified, is secreted in the submaxillary gland.

Faradisation of the membrana tympani likewise produces contractions of the muscles of the tympanum; and Löwenberg[1] has devised a method of rendering these visible by employing a manometer. A piece of cork or india-rubber is made to fit hermetically into the external meatus; and receives, likewise hermetically, a capillary glass-tube containing a drop of coloured liquid. This shows, by its movements, the fluctuation of water in the meatus. The current is applied by means of a copper wire, the inner end of which is in contact with the water in the meatus, while its outer end is connected with one of the poles of the apparatus. The circuit is closed by inserting the other electrode into the Eustachian tube, or placing a moistened sponge-conductor on the skin in the neighbourhood.

Wreden has asserted that, when the faradic current is made to act upon the middle ear, the membrana tympani is retracted. Poorten has denied this, and Löwenberg has endeavoured to settle the question by the use of the manometer. The fluid in the meatus must undergo a change of position, if any alteration in the shape of the membrana tympani occur from faradic contractions of the muscles of the middle ear. The column of water in the manometer falls when the membrana tympani is retracted, and rises if it be pushed outwards. Löwenberg considers this retraction as probably caused by contraction of the tensor tympani muscle rather than by that of the stapedius.

[1] Monatsschrift für Ohrenheilkunde, No. 8, 1872.

4. *Organ of Taste.*—That a peculiar sensation of taste is perceived when the tongue is touched by two heterogeneous metals, had been known long before the discovery of galvanism. M. Sulzer[1] appears to have been the first whose attention was directed to this circumstance. In a paper published by him in the Reports of the Berlin Academy of Sciences, in 1754, the following remarks occur: 'If a piece of lead and a rod of silver be connected with one another, and approached to different parts of the tongue, a sensation of taste is experienced which resembles that produced by vitriol of iron; while, if we employ either of these metals alone, no taste at all is perceived. It is probable that by the connection of the two metals a vibration is produced in the smallest particles, either of the lead or the silver or of both; and that this vibration, which must necessarily affect the nerves of the tongue, produces the taste described.' This is in so far interesting, as it is in all probability the first observation ever made on the physiological effects of galvanic electricity.

If a single pair of zinc and silver be applied to the tongue, the zinc being directed to the tip, and the silver to the back, of that organ, a strongly acid taste is produced under the zinc, and a feebly alkaline taste under the silver plate. These sensations occur not only at the commencement and at the cessation of the current, but also while the circuit remains closed. The effect is most striking when the tongue is at its ordinary temperature, and when the metals have the same temperature as the tongue. When either the metals, or the tongue, or both, are heated or cooled, as far as can be borne without inconvenience, scarcely any sensation is produced; and whatever has a tendency to

[1] 'Recherches sur l'origine des sentimens agréables et désagréables,' in Histoire de l'Académie des Sciences et Belles-Lettres de Berlin, 1754, p. 356.

blunt the sensibility of the tongue, such as acids, pepper, laudanum, spirits, &c., diminishes the effects of galvanism.

Volta found that if a chain was formed of several persons, one touching with his finger the tongue of his next neighbour, and so on, while each of the two who formed the first and last link of the chain took hold of one of the poles of the battery, every person in the chain perceived a distinct sensation of taste.

M. Tripier[1] has directed attention to the circumstance that when the tongue is not in direct communication with the electrodes—as for instance, when one moistened conductor is placed to the right, and the other to the left cheek—the taste is neither acid nor alkaline, but metallic. This taste persists longer after the circuit is opened than when the tongue itself is galvanised, and becomes stronger at the moment of breaking the circuit, which is likewise not the case when the tongue is directly galvanised.

I have frequently observed that a metallic taste, such as of copper or iron, is produced when the positive pole of the battery is applied to the sacrum, and the negative to the nape of the neck. The sensation of taste gradually increases as the current continues to circulate, becomes very distinct at the moment of breaking the circuit, and often continues in a modified manner from five to fifteen minutes after the current has ceased to act. Sometimes it persists for twenty-four hours, or even longer, after the application. Sensitive persons feel it if the current be applied to the nerves of the lower extremities, showing the facility with which portions of the current may travel to nervous districts at a considerable distance from the point of application. A lady suffering from hysteria and amenorrhœa, who was some time ago under my care, felt the galvanic taste distinctly when

[1] Électrolyse et Résolution ; Tribune médicale. Paris, octobre 1868.

the negative electrode was applied to the cervix uteri, and the positive to the abdominal parietes. On some days, however, this patient did not feel the taste, although the galvanic arrangement remained exactly the same; while on other days the taste appeared at once, even when the current used was so feeble that the ordinary pricking sensation on the skin of the abdomen was not felt. This seems to show that there are certain conditions of the nervous system, in which the galvanic current is more easily transmitted to the base of the brain than under ordinary circumstances.

A powerful continuous current applied directly to the tongue, produces not only a specific sensation of taste, but also a flash of light, pain in, and commotions of, the tongue. The induced current produces only pain and muscular contractions, but no taste. The action of frictional electricity on the tongue resembles that produced on it by galvanism. Fowler has compared the taste caused by common electric sparks to the taste of vinegar, and that produced on it by galvanism to the taste of diluted sulphuric acid.

The influence of electricity upon the tongue has been explained in various ways. The most natural supposition is that the taste arises from a peculiar condition of the gustatory nerves produced by electricity, just as the retina responds to the galvanic stimulus by a flash of light, and the auditory nerve by sounds. On the other hand, the differences in the taste beneath the two electrodes have suggested the idea that the effect is due to an electrolytic decomposition of the salines contained in the saliva; as from the chlorides of potassium and sodium which are contained in that liquid, chlorine or hydrochloric acid would be evolved at the positive pole, whence the acid taste; and potash and soda at the negative pole, whence the alkaline taste. But this view does not explain the circumstance that an extremely

feeble current, the positive pole of which does not even redden litmus-paper, nevertheless produces a distinct sensation of taste; while highly diluted acids will visibly redden litmus-paper, even if they are so weak that they cannot by taste be distinguished from distilled water. Frictional electricity, which possesses only very feeble chemical properties, yet produces a marked sensation of taste; and Volta has observed that an acid taste was perceived under the zinc pole, even when the mucous membrane of the tongue was in contact with an alkaline solution, by which the acid, which might have been formed, would immediately become neutralised, so as to produce no physiological effect at all. Another important fact which is opposed to the electrolytic theory, is one observed by Monro, viz. that the taste is perceived, not only when the metals are directly applied to the tongue, but also when pieces of raw or boiled meat are placed between the electrodes and that organ. Now, if the acids and alkalies deposited by electrolysis on the tongue were really the cause of the taste, this latter ought only to be perceived when the tongue is in direct contact with the electrodes; since it is a well-known fact, that the electrolytic deposition of acids and alkalies does not take place within the electrolyte itself, but merely at the ends of the electrodes.

Rosenthal,[1] who has recently investigated this subject, has observed that, if the anode of a galvanic battery be surrounded with a piece of blue litmus-paper moistened with distilled water, and then be placed on the tip of the tongue, the acid appears at first only on that side of the litmus-paper which is turned towards the metal, and not on that which touches the tongue; for if the current acts for a very short time, a red spot is seen on the side turned towards the metal, while there is no change of colour on the opposite side. Nevertheless, the acid taste is perceived immediately

[1] Ueber den elektrischen Geschmack. Du Bois-Reymond's and Reichert's Archiv, 1860, p. 217.

on closing the circuit, that is, before the surface of the tongue is in contact with an acid solution.

Rosenthal also made the following experiment:—The poles of a Daniell's battery of from one to four pairs were connected with zinc plates immersed in two small vessels filled with a solution of sulphate of zinc. These vessels were connected, by means of syphon-tubes, with two other vessels, one of which was filled with a solution of table-salt, and the other with distilled water. A cushion of blotting-paper, moistened with distilled water, was made to emerge from the latter vessel; and a contrivance was interpolated into the circuit which allowed the experimenter rapidly to change the direction of the current. If, therefore, one hand was immersed into the solution of table-salt, and the paper cushion was touched with the tip of the tongue, the current could be made to travel either from the tongue to the cushion, or in the opposite direction. A piece of blue and another of red litmus-paper were then placed on the cushion, so that both touched the tongue; and it was found that the blue paper remained unchanged, while the red one was rendered slightly blue by the alkaline buccal mucus. This occurred with both directions of the current; and it was therefore proved that no perceptible quantity, either of acid or alkali, is set free between the tongue and the cushion. Nevertheless, the sensation of taste was eminently acid when the current moved from the cushion to the tongue, and feebly alkaline when it travelled in the opposite direction.

Rosenthal found that the acid taste is not only more intense, but also more rapidly perceived on closing the circuit, while the alkaline taste is more gradually developed as the current continues to act. The acid taste persists a short time after the circuit is broken, while the alkaline taste disappears immediately afterwards. If the direction of the current be suddenly reversed, the alkaline taste yields

at once to the acid, while the acid taste only gradually merges into the alkaline.

The deposition of free acid or alkali on the surface of the tongue is, therefore, not a necessary condition for the perception of the galvanic taste. The only objection that might yet be raised against this conclusion would be, that Du Bois-Reymond has shown polarisation to take place on the point of contact of two electrolytes; and that therefore acid or alkali might be set free at the end of the tongue or the cushion. But this objection is overruled by Volta's experiment, already mentioned, which shows that the chemical composition of the liquid which is in contact with the tongue has no influence on the perception of taste, since an alkaline fluid has an acid taste, when the galvanic current is made to pass from it to the tongue. Rosenthal has, however, made a special experiment to prove that polarisation has nothing to do with the production of the phenomenon:— One of two persons takes hold of the anode and the other one of the cathode of the battery, after which they touch each other by the tips of their tongues; the one who holds the cathode then perceives the acid, and the other one, who holds the anode, feels the alkaline taste. In this experiment both persons are under similar conditions, except as far as the direction of the current in their tongues is concerned. This is the reverse in each, and both perceive the opposite taste, although one tongue touches the other, and therefore the same capillary layer of liquid covers either tongue. It is therefore evident that the electrolytic theory of the galvanic taste is untenable. The long persistence of the taste after the current has been applied in a peculiar manner (p. 192) is likewise utterly opposed to this theory.

Prof. Schönbein[1] has suggested another explanation. He

[1] Ueber einige mittelbare physiologische Wirkungen der atmosphärischen Elektricität. Henle und Pfeufer's Zeitschrift, 1851, Heft iii. p. 385.

supposes that by the galvanic current air becomes decomposed, and that at the anode oxygen and nitrogen combine to form nitric acid, which would produce the acid taste. But Schönbein does not explain the cause of the alkaline taste which is perceived under the cathode; and the action of a single galvanic pair, or of a few and small electric sparks on air, could not possibly form a sufficient quantity of nitric acid to produce an acid taste, more especially if the electrodes be directed to the nape of the neck. We are therefore led to the final conclusion that the galvanic taste is due to the vital property of the gustatory nerves being roused by electricity.

V.—ACTION OF ELECTRICITY UPON THE MOTOR NERVES AND MUSCLES.

Experiments on Animals.—If a continuous current be directed to a motor nerve of a recently-killed animal, all the muscles animated by this nerve are seen to contract, on closing as well as on opening the circuit, whether the current be direct or inverse. Care must be taken, however, that the electrodes connected with the poles of the battery be placed at two points of the nerve which, although they may be near each other, are at a different height, so that the electric current may traverse the nerve in an oblique direction. If the current were to pass transversely through the nerve, one electrode being applied to the right and the other to the left side of it, at the same point of its transverse section, no contractions would take place.

Luigi Galvani,[1] of Bologna, first observed, in 1786, that when the nerves and muscles of a frog were connected by means of an arc composed of two different metals, the

[1] De viribus electricitatis in motu musculari commentarius. Bologna, 1791. This essay was published five years after Galvani had made his first discovery.

muscles were convulsed. Soon after Galvani's discovery had been made known, Volta[1] found that contractions likewise took place if the nerves alone were enclosed in the circuit. In their first experiments, Galvani and Volta noticed only the contraction produced on establishing the circuit; but another Italian philosopher, Valli,[2] soon afterwards observed another contraction caused by breaking it. It has lately been asserted by M. Duméril,[3] that these observations had been made a long time ago by a Dutch philosopher, Swammerdam, who had shown the experiment to the Grand Duke of Tuscany in 1668. Duméril's assertion has been repeated by Matteucci and Dr. Golding Bird; but a careful analysis of Swammerdam's experiments shows that the contractions he observed were produced by a mechanical irritation of the nerve, and not by galvanism.

The galvano-muscular contractions do not take place in consequence of the motor nerves simply conducting the electric fluid to the muscles; although the nerves are unquestionably conductors of electricity. But the mere conductivity of the nerves does not explain the physiological effect produced by their electric stimulation; for if a wet thread be tightly applied to a nerve so that it becomes thin and reduced to its neurilemma, no contractions can be caused in the muscles animated by it, on applying the electrodes above the point where the nerve has been tied; although by such a proceeding the propagation of electricity is not arrested, since the wet thread conducts equally well as the nerve. Again, a few drops of ether applied to any point of the nerve will suspend the contractions of the muscles, if the electrodes be placed above or at the point where the ether has been applied; the contractions, however, will reappear

[1] Collezione dell' opere del Cavaliere Conte Alessandro Volta. Florence, 1816, vol. iv. p. 134.

[2] Reinhold, Geschichte des Galvanismus, etc. 1792, p. 25.

[3] Annales des Sciences naturelles, 2e série. Zoologie. Paris, 1840, vol. xiii. p. 65.

when the effects of the ether have passed off. Finally, if the nerves of a frog be galvanised which has been poisoned by woorara, no contraction occurs in the muscles animated by these nerves; although woorara does not affect the electric conductivity of the nerves, which remains intact; nor the contractile power of the muscles, for they are seen to suffer commotions if the electric current is applied directly to their tissue without the intervention of the nerves; but the contraction fails to appear because woorara destroys that peculiar force by which the nerves are enabled to produce the play of the muscles. *Hence it results that contractions of the muscles cannot be produced by galvanic stimulation of the motor nerves, unless the nerves be in a state of integrity; and that the galvanic current acts in this manner by rousing the vital properties of the motor nerves.* The visible physiological effect in the muscles occurs at the moment when the density of the current suddenly rises from zero to a certain height, as is the case on making the circuit; and, again, when the density of the current descends from a certain height to zero, as is the case on breaking the circuit. Proceeding from these facts, Du Bois-Reymond[1] has laid down an electro-physiological law for the motor nerves, which he has proposed in the following terms:—'The motor nerve is not excited by the absolute amount of the density of the current, but merely by the variations which occur in the density of the current from one instant to the other; and the physiological effect is the greater, the more considerable are the variations of the density of the current; that is, in proportion as they take place more rapidly, or as they are more considerable in a given space of time.' This affords a striking analogy to the development of induction currents in coils of wires connected with the poles of a battery; since induction currents are only pro-

[1] Untersuchungen über thierische Elektricität. Berlin, 1848, vol. i. p. 258.

duced on making and breaking the circuit of the battery, but not while it remains closed.

By Du Bois-Reymond's law it is easy to explain a number of phenomena which had been observed a long time ago. Physiological effects may be obtained by minor variations in the density of the current; for instance, if the power of the current traversing a motor nerve be suddenly increased; or if another current be suddenly brought to bear upon a nerve which is already traversed by a continuous current; or if a portion of the current passing through a nerve be suddenly diverted into another channel. Variations of this kind are, however, not so considerable, and the physiological effect is therefore not so striking, as that observed on closing or opening the circuit.

It is also easy to understand from Du Bois-Reymond's law the action of faradisation upon the motor nerves and muscles. Induction currents are instantaneous; they consist of great and sudden variations, which succeed each other more or less rapidly, in consequence of the commencement and the cessation of the battery current, and the magnetisation and the demagnetisation of the soft iron. A single induction shock has the same effect as the continuous current on opening or closing the circuit. A contraction appears in consequence of the disturbance of the molecular equilibrium of the nerve; and the muscle becomes relaxed immediately afterwards. But when induction currents succeed each other rapidly, as in the machines used for medical application, the contractions caused by them likewise occur in quick succession, and there is no time for perceptible relaxation. With a certain rapidity of the shocks, the contraction appears continuous, as if produced by the will; but this apparently continuous contraction consists only of a very quick succession of single contractions, the intervals between which are too short to be distinguished.

Du Bois-Reymond's law was for some time believed to be the absolutely correct expression of these conditions, but the later researches of Pflüger, Von Bezold, and others, have caused certain modifications of the same to be adopted.

Pflüger[1] has shown that, although the chief effect is produced by variations of the density of the current, a feeble and perfectly constant current may, under certain circumstances, become a stimulant. The nerve is, according to him, excited as soon as any external force changes, with a certain rapidity, the molecular condition of the nerve, whereas a stationary condition of the same is incompatible with stimulation. Now, during the whole of the time that the current traverses the nerve, this latter is subjected to electrolysis, and its molecules therefore must undergo constant motion. They therefore cannot continue at rest, and tetanus during the passage of the current is produced. That only a feeble current should produce tetanic irritation, while a powerful current is unable to accomplish this, is explained by Pflüger in this manner: the stronger the intensity of the current, the greater becomes the anelectrotonic zone of the nerve (*vide* electrotonus), in which excitability is diminished, while a feeble current acts upon a zone, the excitability of which is augmented.

Von Bezold[2] has followed up Pflüger's investigations, and arrived at the conclusion that the motor nerve is not excited by variations which occur in the density of the current from one instant to another; but that on *closing* the circuit the effect is produced by the current traversing the nerve in a perfectly constant manner; and that on *opening* the circuit, the same takes place in consequence of disturbed molecular equilibrium in the nerve, which persists for some time after the circuit has been opened.

[1] Untersuchungen über die Physiologie des Electrotonus. Berlin, 1859.

[2] Untersuchungen über die electrische Erregung der Nerven und Muskeln. Leipzig, 1861.

He believes that the action of the continuous current is in reality due to its chemical action upon the nerves and muscles, while the induced current differs altogether from the continuous current, and has more complicated effects. Each single shock from an induction machine is composed of three different acts, which have to be separately considered; viz. the rise, the flow, and the fall of the density of the current.

Influence of intensity and direction.—If a feeble continuous current be applied to a nerve, this latter may retain its excitability very long, and is not destroyed, as by mechanical and chemical stimulation. But if the current be powerful, the nerve is cauterised by the chemical action of the battery, especially at the point where the cathode has touched the nerve, for by electrolysis of the salines contained in the latter, caustic alkali is set free at the cathode. If, therefore, a nerve to which such a current has been applied, be afterwards again subjected to the action of a feeble continuous or an induced current, above or at the point to which the cathode has been directed, no effect is produced; but if the same nerve be galvanised or faradised at a point nearer to the muscle, and beneath the cathode, the muscles animated by it may again be caused to contract. A wire rendered incandescent by voltaic electricity destroys the nerve by heat. A feeble induction current has no such destructive effects; but a powerful one, or severe shocks of static electricity, may annihilate the vitality of the nerve by the mere force of the concussion.

The phenomena produced by the electric stimulation of the motor nerves present certain differences according to the *direction* of the current, provided the latter be feeble. When the nerves are in the highest degree of excitability, as is the case immediately after death, and when they have not yet been experimented upon, the contractions are equally powerful on using the direct and inverse current,

and on closing and opening the circuit. But if the nerves have lost a certain degree of their excitability, as is the case some time after death, and when they have been exhausted by experiments, a difference is noticed in the physiological effects. It is then seen that a direct current produces the contraction only when the circuit is established, but not while the current traverses the nerve, nor at the moment when it ceases to pass; and, on the other hand, that the inverse current causes no contractions on making the circuit, nor while it remains closed, but only when it is broken. If more time has elapsed after the death of the animal, or if the nerves have been longer experimented upon, only one contraction will occur, viz. on making the direct current; and finally, all contractility will disappear. These differences in the contractile power of the muscles were first investigated by M. Nobili,[1] of Reggio, who has distinguished five different periods of the excitability of the muscles, as shown in the following table:—

Nobili's Law of Contractions.

	Direct Current		Inverse Current	
	Making	Breaking	Making	Breaking
I.	Contraction	Contraction	Contraction	Contraction
II.	Strong contract	Feeble contract	—	Strong contract
III.	Strong contract	—	—	Strong contract
IV.	Contraction	—	—	—
V.	—	—	—	—

These differences depend upon certain changes which occur in the current proper of the nerves after their separation

[1] Memorie ed Osservazioni edite ed inedite del cavaliere Leopoldo Nobili, Florence, 1834, vol. i. p. 135; and Annales de Chimie et de Physique, mai 1830, vol. xliv. p. 60.

from the body. Nobili's law, however, is not absolute; for in some instances the contrary will happen, viz. a strong contraction on *breaking* the *direct* and on *making* the *inverse* current; and two or even three of these periods of excitability may exist in the same nerve at the same time, provided that it be excited at different points of its length. This depends upon the circumstance that the nerves, after having been separated from their centres, die in a direction from the centre to the periphery, as was first pointed out by Valli and Ritter. The vital energy, therefore, continues longest in the terminal branches of a nerve. From this it may be inferred that the manifold differences noticed in the electro-muscular contractions have not that important physiological bearing which had been attributed to them by previous observers. It is quite true that there are different periods of excitability in the nerves after they have been separated from the animal body; but these never occur in the living nerves, as long as they are connected with the nervous centres; they are merely the result of the fatigue of the nerves which necessarily occurs a certain time after their separation from the body, and after they have been repeatedly subjected to experiments.

Fick has shown that the *force* which is used for the stimulation of a motor nerve, the degree of *irritation* which is set up by it in the nerve, and finally the amount of muscular *work* which is done in consequence, are mutually interdependent, so that the increase or diminution of one inevitably entails an increase or diminution of the two others. He also found that when the duration of the current is prolonged, the irritation is not increased uniformly, but by fits and starts. If the intensity of the current be constantly augmented, the nervous irritation which is set up reaches at last a maximum; but even this limit may be exceeded by prolonging the duration of the stimulation; whereby a *supra-maximal*

effect is produced. This latter somewhat fantastic view has been satisfactorily explained by Lamansky, who found that there is indeed a kind of second maximum, but that this is simply owing to the mode in which the faradic current is interrupted; inasmuch as Fick employed in these experiments not one, but two interruptions of the current, which succeeded each other very rapidly; so that an accumulation of two induction shocks acted upon the nerve.

Inhibitory effects of the closed circuit.—Ritter[1] concluded from some observations on frogs that, when the direct current traversed a motor nerve for some time, it had a paralysing effect on it, while the reverse current tended to augment its irritability. He also discovered that, when an inverse current had acted for a considerable time on the nerve, the muscles animated by it were tetanised on opening the circuit. This phenomenon is called *Ritter's tetanus.*

Volta[2] found that both directions of the current, after a time, rendered the nerve insensible to the stimulus of the same current; but that its excitability could be revived if an inverse current was substituted for the direct, and *vice versâ.* These phenomena are, after their discoverer, called *Voltaic alternatives.*

Rosenthal,[3] who has investigated this subject very carefully, has come to the conclusion that Volta's law as proposed by him is untenable, and that if the continuous current traverses a motor nerve for a certain length of time, it causes a peculiar condition in the same, in which its excitability is *increased* to the opening of the acting current, and the closing of one flowing in an opposite direction; and *diminished* to the closing of the acting and the opening of the opposite current.

[1] Beweis dass ein selbstständiger Galvanismus, etc. Weimar, 1798, p. 119; and Beiträge, etc. 1800, vol. x. p. 142.

[2] Collezione dell' opere, etc. vol. ii. p. 219, *note* (a).

[3] Monatsberichte der Berliner Akademie, December 1857, p. 640.

According to Pflüger, however, Rosenthal's law only holds good for a current of feeble or medium intensity; for if the power of the current be great, the tetanus produced on breaking it is enfeebled on *closing*, and increased on *opening* the circuit, whatever may be the direction of the current. Wundt[1] considers that every current produces after a certain time a change in the nerve, in which the inhibitory surpass the exciting effects; and that a feeble current, if used for a considerable time, has the same action as a powerful current which is employed for a short time, so that under certain conditions the duration and the intensity of the current are equivalent.

That a continuous current may under certain circumstances calm an irritated condition of a nerve, had already been observed by Nobili,[2] who remarked now and then, in the course of his experiments, that prepared frogs became tetanised without any apparent cause, and that this condition suddenly ceased if a continuous current was sent through their limbs in a certain direction; while the tetanus continued if the current moved in the contrary direction. He did not state which was the direction. Matteucci[3] found that when frogs, tetanised by strychnia, were subjected to the action of an inverse current, the tetanus disappeared rapidly, and did not return; the frogs died from the effects of the poison, but without the convulsions which were otherwise the consequence of the absorption of strychnia. On the other hand, he found that tetanus was increased by the passage of the direct current. Together with M. Farina he endeavoured to utilise this property of the current in a patient who suffered from traumatic tetanus in consequence of having been shot through the leg. He caused a current of from thirty to forty pairs

[1] Ueber Verlauf und Wesen der Nervenerregung. Braunschweig, 1871, p. 253.
[2] Memorie, etc. p. 91.
[3] Comptes rendus, etc., mai 1838, vol. vi. p. 80.

to pass along the spine in the direction from the sacrum to the nape of the neck, and introduced the patient gradually into the circuit in order to avoid muscular commotions. The trismus was relieved for a time, circulation and respiration were re-established, and the patient appeared generally comforted, but died nevertheless afterwards, the irritation having been kept up by foreign bodies in the wounded limb.

Another observation of inhibitory effects was made by Du Bois-Reymond, who remarked that in a tetanised frog's limb the gastrocnemius muscle became quiet as soon as the sciatic nerve was laid upon the tendon of the muscle; that is, if the *inverse* current proper of the muscle was made to pass through the nerve; but that the tetanus continued unchanged if the nerve touched the flesh of the muscle, that is, if the *direct* current proper of the muscle traversed the nerve.

Prof. Eckhard,[1] of Giessen, found that if an inverse current of some intensity was sent through a nerve, the excitability of the latter was so much diminished that any mechanical, chemical, or electrical stimuli which would otherwise cause contractions of the muscles, no longer induced them when the current continued to traverse the nerve, whatever might be the point of the nerve to which the stimulus was applied; while a *direct* current would diminish the excitability of the nerve, only at those points to which the electrodes were applied, and at all points beyond the anode; but that it tended to increase the excitability of the nerve on all those points which were beneath the cathode.

Pflüger[2] has shown that Eckhard's method of experimentation is liable to give rise to errors, and has ascertained that if a motor nerve be excited above the point of entrance

[1] Beiträge, etc. p. 25.

[2] Ueber das Hemmungs-Nervensystem, etc. p. 3.

of an *inverse* current which is not very powerful, the contraction is not diminished, but that the influence of the *direct* current of the same strength will diminish the contraction. If the power of the current exceeds a certain degree, the contrary is observed. Eckhard's assertion that the excitability of a nerve subjected to the influence of the inverse current is everywhere diminished, is incorrect; for if the power of the current do not exceed a certain standard, the contraction obtained by exciting a portion of a nerve situated above the electrodes is not enfeebled, but increased. If, however, the current be very powerful, the contraction is rendered less.

Refreshing or Restorative Effects.—Heidenhain [1] has discovered that if the muscles of a frog had lost their excitability in consequence of fatigue or ill-usage, but were not quite dead yet, their excitability could be restored by directing to their substance a somewhat powerful continuous current for half-a-minute or more; and that the inverse current was more effective in this respect than the direct, both as far as persistence and completeness of effect was concerned. These refreshing effects of the continuous current are of the greatest practical importance, and are shown in the most striking manner in cases of disease, where the action of the muscles is either enfeebled or altogether lost.

Dr. Poore [2] has found similarly refreshing effects caused by the application of the continuous current to the motor nerves of healthy men. A person was requested to hold his left arm at right angles to his body, and a weight of nineteen ounces was placed in his palm. In about four minutes the man complained of great pain in his muscles, chiefly the deltoid, biceps and triceps, and said that he could not go on

[1] Physiologische Studien. Berlin, 1856, p. 65.
[2] The Practitioner, January 1873, p. 39.

with the experiment. The anode was then placed in the axilla, and the cathode to the painful parts, when he at once exclaimed, 'All the fatigue is gone, and I feel as strong as when I began.' Care was taken not to support the limb with the electrodes, and one of them was even an additional burden to the arm. The current was not strong enough to produce involuntary muscular contractions. One man could thus hold his arm out for $13\frac{1}{2}$ minutes with galvanism, and only, with the greatest exertion, 6 minutes without. One said that when the arm was used for such an experiment without galvanism, it ached all day afterwards; but with galvanism it did not give any trouble. The endurance of voluntary muscular action is therefore considerably increased by the continuous current. That muscular force is also increased by the same means is shown by squeezing a dynamometer, and then galvanising the flexors of the fingers; care being taken that the position of the dynamometer in the hand, and the position of the patient, should remain the same throughout the experiment. The anode was directed to the inner border of the biceps muscle, and the cathode to the inner side of the tendons of the biceps, at the bend of the elbow. In one experiment, the result, in pounds, of each successive squeeze, was as follows:

Without galvanism,	55	55	55	50	47	44	42	40 = 388.
With „	73	65	63	60	56	54	53	53 = 477.

This gives 89 pounds in favour of galvanism, or an average of 11·125 pounds per squeeze. The experiment with galvanism was made about ten minutes after the first, when the hand was still tired from the first experiment. When the trial of strength with galvanism preceded the one without, the difference became even greater:

With galvanism,	73	76	72	70	70	70 = 431.	
Without „	60	47	45	40	46	41 = 279.—Total difference 142 pounds.	

Electrotonus.—Pflüger has shown that a continuous current which traverses a certain length of the nerve (the polarising current), divides this latter into two physiologically different sections or zones, which pass into one another at a point where the condition of the nerve is unchanged (*point of indifference*), and which is situated at an equal distance from either of the poles. One of these sections or zones shows the condition of increased excitability (*catelectrotonus*), while the other section is in a condition of diminished excitability (*anelectrotonus*). The zone of increased excitability is in the neighbourhood of the cathode, while the zone of diminished excitability is in the neighbourhood of the anode. The condition of increased excitability is propagated from the cathode towards either side, and the condition of diminished excitability is propagated from the anode towards either side. This alteration of excitability in the extra-polar portions of the nerve diminishes in the same ratio as the distance at which they are from the electrodes increases, and at a certain distance it disappears altogether. As a rule the positive zone of the nerve diminishes in extent proportionately to the intensity of the current; and if the latter be very feeble, almost the whole portion of the nerve included between the two electrodes may be in a state of increased excitability.

If the polarising current passes for a longer time through the nerve, and if its intensity is at the same time increased, the point of indifference is removed from the anode, and approaches more nearly to the cathode; that is to say, the zone where there is diminished excitability increases in extent, while that where there is increased excitability proportionately diminishes; and when the duration or intensity of the current has attained a certain degree, the zone of augmented excitability is reduced to a very small

space in the neighbourhood of the cathode. If a current of extreme power be used, these conditions may be reversed. On breaking the polarising current, these alterations of excitability gradually become less marked, and at last vanish completely; but previous to that, opposite modifications of excitability occur in the portions which have been polarised. In the anelectrotonic portion, where during polarisation excitability had been diminished, there is for some time an increase of the same, which is called the *positive modification* of excitability. On the other hand, the catelectrotonic portion shows for a short time a diminution which is called the *negative modification* of excitability; this, however, rapidly passes into the positive one, which then gradually disappears.

Pflüger has likewise shown that the polarising current changes not only the excitability of the nerve, but also the faculty of the latter to transmit stimulation; inasmuch as that portion of the nerve which has its excitability diminished, offers a greater resistance to the transmission of the stimulation, and that this resistance further increases with the duration and intensity of the polarising current.

The principles of electrotonus once established, Pflüger was naturally led to the study of the law of contractions; and found *that the nerve is excited by the appearance of catelectrotonus, and the disappearance of anelectrotonus, but not by the appearance of anelectrotonus or the disappearance of catelectrotonus.*

The following table shows

Pflüger's Law of Contractions.

Strength of Current	Direct Current	Inverse Current
Feeble	Making: contraction	Making: contraction
	Breaking: rest	Breaking: rest
Medium	Making: contraction	Making: contraction
	Breaking: contraction	Breaking: contraction
Strong	Making: contraction	Making: rest
	Breaking: rest	Breaking: contraction

Catelectrotonus corresponds to a greater mobility of the molecules of the nerve, while anelectrotonus corresponds to a lower degree of mobility of the same.

Effects on living nerves.—When the motor nerves are in their normal connection with the nervous centres, the application of galvanism produces somewhat different effects from those which are observed in nerves separated from the body of the animal. It was first pointed out by Valentin and Bernard, that if a nerve was galvanised while still connected with the spinal cord of the living animal—that is to say, in its normal physiological condition—a contraction was produced *only on establishing the circuit*, whatever might be the direction of the current. But if the nerve was fatigued by any cause, as, for instance, by prolonged experiments, or by the action of heat during summer, or if the nerve was ligatured or divided above the point touched by the electrodes, two contractions were produced, one at the commencement and another at the cessation of the current. These two contractions are, therefore, an indication of a fatigued state of the nerve. If the fatigue becomes greater, contractions are only produced on making the direct and breaking

the inverse current; finally, only a single contraction is obtained on making the direct current. These four different periods succeed each other more rapidly in summer than in winter, as cold weather is favourable to the continuance of the excitability of the nerve.

M. Eulenburg,[1] of Berlin, was the first to investigate electrotonus in the living man, and came to the following conclusions:—Certain motor nerves which are easily accessible to the current, such as the spinal accessory, the median, ulnar, and peronæal nerves, and certain muscles which are reached without difficulty, such as the deltoid and the opponens pollicis, may be made to assume the electrotonic state during life. He placed the cathode of an induction apparatus on the nerve, and the anode on the sternum; after which he sent a direct or inverse continuous current through the nerve above the cathode. It was then seen that if the inverse current was used, a negative, and if the direct current was used, a positive, modification of excitability took place in that portion of the nerve which was behind the electrodes; and that the extent of the positive and negative modification, and the duration of the subsequent effects, increased in proportion to the power of the current and the length of time during which the circuit remained closed. The muscles likewise assumed a distinct positive modification with catelectrotonus, while the negative modification with anelectrotonus was less perceptible.

M. Samt's[2] observations on this subject do not quite agree with those of Eulenburg. According to Samt, this is due to the circumstance that in Eulenburg's experiments the excitability of the nerves is modified, not only by the pressure of the electrodes upon them, but also by the effect of the induced current which is used as a stimulant.

[1] Deutsches Archiv für klinische Medicin, 1867, Bd. iii. p. 117.

[2] Centralblatt für die med. Wiss. November 1868.

Von Bezold[1] has found that during electrotonus the power of conduction or the velocity of nervous force is diminished, in the anelectrotonic as well as the catelectrotonic portion of the nerve; and that if the nerve be excited by *closing* the circuit, more time is required for making the contraction appear than if it be excited by *opening* the circuit. This is more especially the case if the inverse current be used, and less so with the direct current. Von Bezold believes that whenever a continuous current enters a nerve, a certain period is necessary for preparing the nerve to respond to the current, and that this time of preparation is the shorter the greater the power of the current. According to the same observer, the conduction is also retarded in the *muscular* fibre during the electrotonic state; but this is exactly limited to the place where the electrodes are applied, and does not extend beyond them, as it does in the nerve.

This conclusion has been pretty generally adopted; but Dr. Rutherford[2] has shown that Von Bezold used a too powerful current in his researches, and thereby invalidated the results. He employed a current of seven pairs of Grove's battery, and allowed it to flow through the nerve for at least three minutes before the observation of its influence on the velocity of nervous force was taken. The anode as well as the cathode of this current were found to diminish the velocity; while, according to Dr. Rutherford, if a feeble current be used, the *cathode increases*, while the *anode diminishes* the velocity. This agrees with the general law established by Pflüger.

Further researches on the physiology of electrotonus in the living man have been made by Brenner,[3] Erb,[4] Brückner,[5]

[1] Loc. cit. p. 109.
[2] The Lancet, March 4, 1871.
[3] Loc. cit. vol. ii. p. 77.
[4] Deutsches Archiv für klinische Medicin, vol. iii. p. 238.
[5] Deutsche Klinik, 1868. No. 41, 42.

Runge,[1] and Filehne,[2] but the results at which they have arrived are neither very clear nor very important. The difficulties which are encountered in investigating this subject, have been well stated by M. Cyon.[3] At first we have to find a motor nerve which runs a sufficient way near the skin, to be easily reached by the polarising and the exciting current; then it is necessary that the polarising electrodes should be applied to the nerve in such a manner as not to be displaced during the whole time of the passage of the current, as otherwise the intensity of the current traversing the nerve would be considerably altered; furthermore, it is imperative to avoid the errors which might result from the pressure of the electrodes upon the nerve; the exciting current must be applied in such a manner that no fraction of it can flow through the region traversed by the polarising current; it is necessary to have an exact means by which to measure the modifications of excitability produced; and finally, we must eliminate as far as possible the disturbance which might be caused simply by the influence of the experiments.

Cyon selected for his researches the ulnar nerve at the arm, where it is easily accessible, and may be fixed on the humerus; to this nerve he applied the polarising continuous current; while the exciting faradic current was directed below this region, one electrode being placed just above the elbow, and the other near the cubito-carpal articulation. In order to prevent any displacement of the nerve with regard to the electrodes, the whole arm was surrounded with a mould of plaster of Paris, and the electrodes fixed to one another by means of a screw; they were, moreover, so fixed on the arm as to render displacement impossible. Before each ex-

[1] Deutsches Archiv, etc. vol. vii. p. 356.
[2] Ibid. vol. vii. p. 575.
[3] Principes d'électrothérapie. Paris, 1873, p. 130.

periment the nerve was faradically searched, and its way traced with ink on the skin, after which the electrodes were again applied to it in order to ascertain whether it was always in the same place. The pressure of the electrodes upon the nerve was avoided by resting them, not on the arm, but on the plaster of Paris mould. For measuring the modifications of the excitability of the nerve, Cyon measured the force of the farado-muscular contraction produced by means of a myographion, which traces on a register the contractions of the adductor muscle of the thumb. The plaster of Paris mould which surrounded the arm prevented all movements except those of the muscles just named; the hand was completely surrounded by it, and the mould had only some fenestræ for the electrodes and for the thumb, which latter could therefore execute its movements without hindrance. The polarising current was furnished by twenty to twenty-five pairs of Siemens and Halske's (Daniell's) battery; metal plates, covered with lint or sponge, were used as electrodes, and they were placed at a distance of 2 or $2\frac{1}{2}$ inches from one another. The exciting current was furnished by Du Bois' sledge-apparatus, and both currents were interrupted by means of a Du Bois' key (p. 131). The experiment is therefore performed in the following manner :—

After the position of the ulnar nerve has been made out by faradisation, and traced on the skin, the arm is placed in the mould; the adductor of the thumb is then put into communication with the myographion, and the two electrodes of the polarising current, solidly fixed to the plaster, are placed on the nerve, while the circuit of the battery is open. The nerve is then faradised at some point below the polarising electrodes, with a current of moderate power. When the adductor muscle has traced its contraction, the circuit of the polarising current is closed for some time, after which the adductor is again made to contract. During the experi-

ment the arm is placed in a horizontal position, with all the joints extended.

The following are the results at which Cyon has arrived :— As a rule, the modifications which the electrotonised human nerve undergoes are the same as those observed in the nerve of the frog's limb; that is to say, immediately after closing the circuit, the excitability is *increased* in the neighbourhood of the *negative* pole. This increase augments with the duration of the passage of the polarising current, until it attains a certain maximum beyond which it cannot go, however much the passage of the current may be prolonged. Immediately after the interruption of the polarising current, excitability diminishes in the catelectrotonic region, but this only continues for an instant, and afterwards gives way to an augmentation which lasts longer, and only slowly and gradually subsides into the natural condition. After breaking the current, therefore, a negative modification of an instantaneous duration takes place, which passes into a longer positive modification, and at last into the normal state.

On the contrary, the excitability is *diminished* in the neighbourhood of the *positive* pole some time after closing the polarising circuit. Immediately after this is opened, there is a considerable increase of excitability, or positive modification, which appears to be more considerable when the current has acted for a longer time. These experiments, therefore, agree completely with the results obtained by Pflüger on the rheoscopic nerve; but considerable exceptions to the rule are not unfrequently observed in the living human nerve, not only in healthy subjects, but also in persons suffering from nervous affections.

Cyon explains the exceptions encountered in healthy subjects by the circumstance that the nerves on which the experiments are made are still in connexion with the

nervous centres. Claude Bernard has shown (p. 212) that the law of contractions is very different in nerves which are separated from, and in those which are still in connexion with, the body. Central innervation is therefore shown to exercise an influence on the production of the phenomena. On the other hand, it must not be forgotten that, even in the experiments on frogs, from time to time irregularities are encountered, and that nerves occasionally refuse a response which is, on the whole, absolute. The exceptions which are met with in patients suffering from nervous affections cannot disprove the general correctness of Pflüger's laws, which may therefore be considered valid, not only for the frog's limb, but also for the living human nerve. The pathology of the nervous system will, on the contrary, be most materially advanced if the alterations in the state of anelectrotonus and catelectrotonus become better known. Changes in the molecular condition of the nerves may be made manifest by noting variations in the response given by the nerve to the current; and as we may, *ad libitum*, increase or diminish the excitability of a nerve, we may look forward to a more scientific and at the same time successful treatment of certain nervous affections, by inducing either anelectrotonus or catelectrotonus in the living nerve.

Cyon has likewise studied in the human subject the connexion between the degree of nervous stimulation and the force of stimulants employed. Fick has shown (p. 205) that in the rheoscopic limb the force of stimulation, nervous irritation, and muscular work, are in complete interdependence, inasmuch as the amount of muscular work is simply a function of nervous irritation, which itself is a resultant of the stimulating force. The muscular work may therefore be utilised for measuring the force of nervous irritation. Cyon used the same mode of experimentation as above for ascer-

taining whether the same law obtained for the living human nerve as for the rheoscopic limb, and found that such is the case. The extent of muscular contraction increases proportionately to the force of stimulation. There is a maximum value of contraction ; and when this is attained, any further increase of stimulating force will not give more contraction.

Electrotonus is only produced by galvanisation and not by faradisation. This is the principal cause of the therapeutical superiority of the continuous over the induced current.

The avalanche theory.—Pflüger has shown that different parts of the trunk of a spinal nerve have different degrees of electric excitability. If, for instance, the sciatic nerve of the frog's limb be faradised, at first near the gastrocnemius muscle, and afterwards at a distance from it, a more powerful contraction takes place in the latter than in the former case, in spite of the intensity of the current having been the same in both experiments. This he explains by comparing the passage of nervous force through a nerve with a rush of an avalanche over a precipice, gathering force as it descends. The experiments on this point which have been lately made by Dr. Rutherford,[1] have however shaken Pflüger's avalanche theory, and appear to show that the excitability of any point in the trunk of a spinal nerve behaves inversely as the distance of that point from the nerve-centre. Dr. Rutherford does not think this great excitability owing to a difference in the blood supply, because removal of the heart previous to exposure of the nerve made no apparent difference in the result ; but considers it more likely that the cause is a direct action of the nerve-cell upon the nerve-fibre. Mr. Power has suggested that the results obtained by Dr. Rutherford might be explained

[1] Journal of Anatomy and Physiology, 1871, p. 329.

by the circumstance that the white substance of Schwann is thinner in the nerve-fibre nearer to the nerve centre than it is at a distance from it; and that the electrical stimulant would act more powerfully where this substance was thinner; but careful measurements made by Dr. Rutherford have not shown any difference between the thickness of the white substance at the different points of distance from the spinal cord, so that Mr. Power's explanation cannot be received as the true one.

Remak's galvano-tonic contractions.—A current of very great power produces, according to Remak,[1] tonic contractions during the whole time that the circuit is closed, and likewise on opening it. Remak observed that, if a very powerful current was sent through certain nerves, tonic contractions would occur in the antagonistic muscles. When he acted upon his own median nerve, there was a tingling sensation in all the parts animated by that nerve, and a contraction, which gradually increased, in the extensors of the wrist and of the fingers. The hand was raised to an angle of about 45°, and the fingers were extended. This contraction continued as long as the battery current circulated in the nerve, but the hand dropped on opening the circuit. He was able to resist the involuntary extension of the hand while the circuit was closed, since he preserved the full force of volition over the muscles animated by the median nerve; but as soon as he ceased to resist, the wrist and the fingers were again extended. The same took place if he sent a continuous current through the radial nerve, by placing one electrode to a point between the biceps and triceps muscles, where this nerve is easily accessible, and the other electrode on the back of the fore-arm, where the interosseous nerve is superficial. This proceeding caused tonic contractions of the muscles animated by the median and

[1] Galvanotherapie der Nerven- und Muskelkrankheiten. Berlin, 1858, p. 56.

ulnar nerves, that is to say, flexion of the hand and the fingers. Remak termed them *galvano-tonic contractions*, in order to distinguish them from the clonic contractions which are caused in the muscles by the induced current or a rapidly-interrupted continuous current; and he believed them to be due to variations in the density of the current, inasmuch as the resistance in the circuit varies as the current continues to circulate. For producing galvano-tonic contractions a current of great power is required. Usually this current causes much pain; and in some instances the pain may be severe, and yet no galvano-tonic contractions will occur; while in other instances less pain may be experienced, and the contractions be well marked. If a somewhat considerable extent of the nervous trunk be traversed by the current, the contractions are more easily produced than if only a small portion of the nerve be acted upon. In some cases it is sufficient to employ from twenty to thirty pairs of Daniell's battery charged with acid; in other instances fifty are necessary. The phenomena may be different on different days in the same individual; so that at first contractions occur in the muscles animated by the nerve which is traversed by the current, while at another time the antagonistic muscles are affected; sometimes even a struggle for preponderance may be observed between the different groups of muscles, so that at first there is flexion, and some time afterwards extension, while the current continues to traverse the same nerve. In Remak's opinion these contractions are not produced by direct stimulation of the nerves, but must be considered as reflex movements caused by the propagation of the current to the nervous centres. It is however most probable that the incongruous phenomena described by Remak are due to galvanic maltreatment of the nerves and muscles.

Law of contractions in man.—If in a healthy man a

feeble or moderately powerful continuous current be made to act on a motor nerve, *there is only a contraction on establishing the circuit*, whatever may be the direction of the current, and whether the closing and opening is effected with the positive or the negative pole. *At the cessation of the current there is no contraction at all.* The negative pole is, however, in so far more effective than the positive, that, if the cathode be applied to the nerve, and the anode to the muscle, a contraction on closing will be produced by less galvanic power than if the position of the electrodes be reversed. When the continuous current is used in this manner, the power of the contraction produced on closing the circuit gradually increases, while, if the induced current be used, the extent of the contractions remains the same, or becomes more feeble after a time.

Benedict,[1] who alludes to this increase of galvano-muscular contractions during the application of the continuous current, ascribes it to an increase of nervous excitability in consequence of the application of the galvanism, and is supported in this by Brenner and Ziemssen; but this only partially explains the circumstances of the case, the chief cause of the phenomenon being, in my opinion, that in consequence of the application of the current the resistance of the skin is considerably diminished.

Soon after the current has been made to act, the skin is seen to assume a pinkish hue, in consequence of dilatation of the blood-vessels of the corium; and as the blood is the chief conducting medium of the human body, an increased quantity of it in any organ must of course improve the electric conductivity of the same. This is the reason why a current which at first produces no contractions generally causes powerful movements after the circuit has been made and broken ten or twenty times, or after the electrodes have

[1] Electrotherapie. Wien, 1868, p. 32.

remained fixed for half a minute or a minute on those points of the skin which correspond to the motor nerves.

The galvano-muscular contractions are much more marked if a portion of the nervous centres is included in the circuit, than if merely the motor nerve and muscle be acted upon. A current which, if applied from the peronæal nerve down to the foot, will not produce any motion, does so if one electrode be placed to the lumbar portion of the spine and the other to the peronæal nerve; and even more so, if one electrode be placed to the cervical portion of the spine and the other to the peronæal nerve.

With the continuous as well as with the induced current, the cathode preponderates over the anode. This is best shown by stimulating two corresponding nerves, say the right and the left median nerve, in the same person at the same time. If the cathode be placed to the right, and the anode to the left, median nerve, the effect will be greater in the right than in the left arm; and if the direction of the current be then reversed in the metallic circuit, so that the cathode is made to act on the left, and the anode on the right, median nerve, the effect will be greater in the left than in the right arm.

If the intensity of the current be increased, an effect takes place not merely on closing, but also on opening the circuit; and if it be further increased, contractions occur while the circuit remains closed. These contractions increase in force proportionately to the intensity of the current, and at last become tetanic.

In order to distinguish the effect of either of the poles separately, it is necessary to operate with unpolarisable electrodes, in order to eliminate the effect of the current on the sentient nerves, and consequently reflex movements; and to use the rheostat (p. 54), in order to graduate in the finest possible manner the power of the current. It is also

necessary that the current should be made and broken in the metallic circuit, the electrodes meanwhile remaining stationary on the skin. Ziemssen,[1] who has made a series of accurate observations on this subject, has come to the following conclusions:—

a. The lowest intensity which has any effect at all upon the motor nerve, produces contraction on closing at the cathode;

b. the next degree causes a stronger contraction on closing at the cathode, and a feeble contraction on opening at the anode;

c. a further degree causes the same contractions as in *b.*, and moreover a feeble contraction on closing at the anode;

d. the next degree of power produces tonic contractions at the cathode, which continue after the contraction observed on closing.

e. another increase of intensity causes contraction on opening at the cathode; the other contractions are stronger, and the tonic contraction at the cathode is more energetic.

f. The highest degree of intensity causes slight tonic contraction at the anode, all the other contractions being extremely powerful.

Brenner's[2] law of contractions is nearly identical with that of Ziemssen.

Voltaic alternatives.—Voltaic alternatives, caused by reversing the direction of the current in the metallic circuit, while the electrodes remain on the skin, cause a more energetic stimulation of the motor nerves than simply making or breaking the current. A current which is so gentle as not to cause any effect, either on closing or on opening, will cause a decided contraction if a voltaic alternative be imparted to it. Brenner has well explained

[1] Loc. cit. p. 80. [2] Loc. cit. vol. ii. p. 45.

this, by showing the effect to be due to a double difference being established at the two poles. If six cells are used, there is the effect of a current which rises from 0 to 6, on closing; and if the circuit be opened, there is the effect of a current which rapidly falls from 6 to 0. In either case the difference is = 6. But on causing a voltaic alternative, the current falls at one pole from + 6 to — 6, while on the other it rises from — 6 to + 6. The difference is therefore no longer = 6, but = 12. During this play of the commutator, the cathode retains its preponderance over the anode, inasmuch as the effect is stronger at the negative pole which has at first been the positive, than at the positive pole which has at first been the negative.

The increase of excitability is particularly great if the voltaic alternatives are frequently repeated, and still more, if this repetition is very rapidly effected.

The Striped Muscles.

In previous editions of this work I have fully discussed the question whether there is such a force as inherent muscular irritability—vis musculosa insita—acting independently of the immediate instrumentality of the motor nerves, and have answered the question in the affirmative. Since that time, the proofs for this inherent irritability of the muscular fibre have so accumulated, and have been so generally accepted by physiologists, that only few dissentient voices are now heard in the matter. I therefore do not consider it necessary to enter now as fully into this subject as I have done on previous occasions; and I will only say that the most convincing argument for the existence of inherent muscular irritability has been furnished by Claude Bernard's observations on the influence of electricity on woorarised frogs.

Bernard[1] took two frogs, and poisoned one of them by inserting a small piece of woorara under its skin. When, at the end of five or six minutes, the frog had ceased to show signs of life, the poison was withdrawn. A portion of the lumbar nerve of each of the frogs was then faradised successively, with the results that the muscles of that frog which had not been poisoned were convulsed, while not the slightest twitching occurred in the muscles of the poisoned frog. On the other hand, when the electrodes were directly applied to the muscles, both frogs suffered commotions, and it appeared that the poisoned frog preserved this property even for a longer time than the one which had not been poisoned.

Eckhard objected to this experiment that it only showed paralysis of the large nerves, but not of the small intra-muscular nervous filaments, which might have escaped the paralysing lesion; but Bernard has shown that the motor nerves and muscles lose their excitability from the centre to the periphery (*Valli and Ritter's law*) only if they have been previously separated from the nervous centres. When the sciatic nerve has been cut off from its connection with the cord, faradisation of the trunk of the nerve will, after a time, no longer cause muscular contractions; while, if branches of the nerve are faradised nearer to the periphery, the muscles are still seen to move. If, however, the nerve be kept in its normal physiological connection with the cord, *it loses its properties in the inverse ratio, namely, from the periphery to the centre.* If, therefore, the crural nerve of a frog is laid bare, and contractions are no longer produced by faradisation of the nerve near the muscles, these latter will still respond if the nerve be faradised near the cord; and if the whole nervous trunk has lost its excitability,

[1] Comptes rendus, vol. xxxi. p. 533.

the muscle may yet be made to contract by faradisation of the anterior root of the nerve. This is the way in which the nerves lose their excitability if animals die from hæmorrhage or from woorara; and the two different modes of death of the nerves may be demonstrated in one and the same animal. Bernard has shown that if the lumbar nerves of the *right* side of a frog be divided, and the animal be afterwards poisoned by woorara, the nerves lose their excitability in the direction from the centre to the periphery (*Valli and Ritter's law*) on the *right* side, where there is no longer any connection between the nerves and the spinal cord; and that they die in the direction from the periphery to the centre (*Bernard's law*) on the *left* side, where that connection is still kept up. The terminal branches are therefore the first, and not the last, which are destroyed by woorara; and as, in spite of the destruction of the properties of these nervous fibres, the muscles nevertheless readily respond to the faradic stimulus, the existence of inherent muscular irritability is indisputably proved.

Von Bezold[1] found, in his experiments with woorara, that the contractions of the muscles caused by direct excitation of their fibres, after removal of the nervous influence, had the same character as the contractions induced in muscles which had not been poisoned. According to this observer woorara acts on the intra-muscular nerves by retarding the propagation and transmission of the stimulation from the nerve to the muscle; this retardation increases as time goes on; and at last merges into complete annihilation of the vital properties of the nerve. The same takes place in the nerve-trunks, although there the effect is not so rapidly produced as in the intra-muscular nerves, and larger doses of the poison are necessary for causing this effect. The maximum

[1] Untersuchungen über die Einwirkung des Pfeilgiftes. Reichert's und Du Bois-Reymond's Archiv, 1860, p. 168.

diminution of the velocity of propagation in the trunk of the sciatic nerve of the frog was from 26 mètres to 5·5 mètres in the second.

According to Brücke the striped muscles of woorarised frogs are nearly insensible to the interruption of a current which is of very short duration; and even the unpoisoned muscle does not respond by contraction to an extremely short interruption of a continuous current traversing a nerve.

The contractions produced by applying electricity directly to the muscular substance, present certain peculiarities which are worth mentioning.

If the current be directed to a motor nerve, the whole set of muscles animated by that nerve enters into contraction; but if the current be directly applied to a muscle, only those fibres are seen to contract which are actually traversed by it. If it be intended therefore to cause the whole substance of a muscle to contract, one of the electrodes must be placed on its upper, and the other one on its lower end. A current of greater intensity is required for producing muscular contractions without the intervention of the nerves than is necessary for causing them by stimulation of the nerves. *Hence we may conclude that the molecular equilibrium of the nerves is more easily disturbed by electricity than the molecular equilibrium of the muscles.*

The faradic contraction of a muscle is generally composed of two elements: viz. of direct stimulation of the muscles, and of stimulation of the intra-muscular nerves. The contraction is most powerful if the electrodes are directed to points where the motor nerves are easily accessible, but by a sufficiently strong current contractions may be induced even if the electrodes be placed on points where dissection does not show the existence of motor branches.

It was formerly believed that if a continuous current were directly applied to a muscle, a contraction was only produced

on closing and opening the circuit; but Wundt, Von Bezold, and Fick, have shown that the current may cause contractions not only on making and breaking the circuit, but also while it remains closed, and that they increase in proportion to the intensity of the current.

Onimus,[1] who recently experimented on the body of a criminal soon after decapitation, found that muscular contractility is not lost simultaneously in all the muscles, but that there are considerable degrees of difference in this respect. The first to lose their excitability are the diaphragm and the tongue, after which come the facial muscles. The masseter retains its faradic excitability longer than any other muscle of the face. Within two-and-a-half or three hours after death, the contractility is entirely lost within the sphere of the portio dura. In the limbs the extensor muscles are the first to die, while the flexors retain their excitability about an hour longer. Five or six hours after death, the muscles of the trunk still answer to faradisation; and the abdominal muscles are particularly tenacious in this respect. Long after the muscles of the extremities have become insensible to the faradic stimulus, the abdominal muscles, when exposed to the air and cut up, may still be seen to contract. This corresponds with the clinical fact that in every form of general palsies, the abdominal muscles are the last to suffer; and it is well known that, in many forms of paralysis, the extensors suffer more severely and sooner then the flexors.

In proportion as muscular contractility becomes enfeebled, the mode in which the contraction presents itself is altered. The muscular fibres appear to rise just at the point of contact with the electrodes, while the intermediate parts answer very slowly; gradually these do not

[1] Le Mouvement médical. Paris, février 1873.

answer at all, while a response still takes place at the electrodes. At this stage the muscles do no longer answer to percutaneous faradisation, but may still respond to the same stimulus applied directly to their tissue.

We shall see in the fourth chapter that the loss or preservation of farado-muscular excitability may be used for rendering the diagnosis between real death and apparent death, or trance, perfectly certain.

Many interesting physiological facts have been elicited by the application of electricity to the study of the functions of the muscles of the living body; and no observer has been more diligent or happy in his researches on this subject than M. Duchenne (de Boulogne).[1]

It is true that the deep strata of the muscles, covered by the superficial ones, will not clearly show such phenomena. But here pathology has come to the help of physiology. In progressive muscular atrophy the superficial muscles are destroyed, and the impediments to the passage of electricity cleared away, so that in such cases the function of nearly every muscle in the living body may be ascertained. The opinions previously held on the functions of the muscles have thereby been considerably modified. One of the most interesting facts established by Duchenne's researches is, that the extensor communis digitorum muscle has no influence on the extension of the second and third phalanges of the fingers, but only on the first; that the interossei and lumbricals extend the second and third phalanges of the fingers, and bend the first; and that the flexor sublimis and profundus muscles bend the second and third phalanges, but not the first. This has been proved by pathological observations in cases of lead-palsy and muscular atrophy.

[1] De l'Électrisation localisée, et de son application à la physiologie, la pathologie et la thérapeutique. 1st edition, Paris, 1855; 2nd edition, 1862; 3rd edition, 1872.

In lead-palsy the extensor digitorum is paralysed, but not the lumbricals and interossei. We therefore find that, in this affection, the power of extending the second and third phalanges is not interfered with, but that the first phalanges cannot be extended. On the other hand, cases occur where the extensor digitorum has not suffered, yet the hand has assumed the form of a bird's claw; the interosseous spaces are deeply hollowed; the parts are altogether wasted; the first phalanges are in a state of extension, but the second and third are flexed. This condition of the hand is owing to paralysis and atrophy of the lumbricals and interossei, and is often cured by faradisation or galvanisation of the suffering muscles.

M. Duchenne has given special attention to the function of the muscles of the face, in order to arrive at a knowledge of the mechanism of physiognomical expressions. If there were not in every face a tonic predominance of certain muscles, most physiognomies would be alike, as the muscles have the same direction, insertion, and strength, and the bones only differ in bulk. The facial muscles have only a very small surface, yet faradism may be localised in each one singly, so as to produce isolated contractions of the same. A good way to show the part which every muscle plays in the different physiognomical expressions, is to faradise the facial muscles of a man who has died a short time before the experiment, and whose muscles still retain their excitability; for the living man, when faradised, always mixes involuntary movements with the contraction of the stimulated muscle; which, of course, impedes the observation of the individual action of the muscles. The action of the facial muscles is, however, shown with the greatest distinctness in patients suffering from anæthesia of the fifth cerebral nerve, in whom the muscles may be faradised without causing any pain, and therefore without the

production of reflex movements; but cases of this kind are, unfortunately for clinical demonstration, very rare.

Duchenne has given the following account of the physiognomical action of the muscles of the face, as shown by faradisation:—

The *frontal* muscle, when slightly contracted, cheers up the face; when more contracted, it expresses doubt or surprise; and when in the highest degree of contraction and united with other muscles, it gives the expression of an agreeable surprise or of terror. It also produces horizontal wrinkles in the forehead, and when it is paralysed, these wrinkles disappear.

The *pyramidales nasi*, which are in intimate connexion with the frontal muscle, and are therefore considered by many anatomists to be identical with it, are nevertheless antagonists of the same; they give a sad expression, and, when more contracted, a threatening one. It forms a striking contrast to see these two opposite movements produced in so small a space as the level of the eyebrows.

Isolated contraction of the *orbicularis palpebrarum* expresses contempt; that of the *corrugator supercilii* reflection, and when united to the *pyramidalis*, malice. The *platysma myoides* gives an expression of pain; united with the frontal muscle, it expresses terror; and, with the pyramidalis, rage. Contraction of the *triangularis nasi* gives a sensual expression. The *zygomaticus major* always expresses mirth, from a gentle smile to the most boisterous hilarity; united with the frontalis, it gives the expression of an agreeable surprise; and with the platysma myoides, the sardonic laugh. The *zygomaticus minor*, on the contrary, gives a melancholy air. The *levator alæ nasi*, and *labii superioris*, is the crying muscle of children, and produces an ugly grimace. By the contraction of the external fibres of the *orbicularis oris*, the lips are protruded, as for

kissing and whistling: the internal fibres press the lips against the teeth, as is done by players of the clarionet, for pinching the reed of their instrument between the lips. The *levator menti* is the only muscle in action in persons who repeat their prayers inaudibly, as is often seen in Catholic churches. The *triangularis oris* expresses sadness; in children it is the precursor of tears; in the maximum of its contraction it expresses disgust.

The method of faradising these and other muscles will be described in the third chapter.

Generally the most striking result of electro-muscular contractions is an *increase of heat and bulk* in the parts acted upon.

It had already been noticed by Becquerel aud Breschet[1] that an increase of temperature took place in muscles which had been made to work for some time consecutively; and that the heat in the biceps of a man who had been sawing wood for five minutes at a time, was 1° C. above the heat noticed previous to it. Helmholtz,[2] who experimented on frogs, found that circulation and the heat of the blood had nothing to do with this increase of heat, but that it was solely owing to muscular contraction. Prof. Ziemssen[3] was the first to make systematic researches on this point, on healthy as well as on paralysed muscles, in the human subject. He used a thermometer on which the twentieth part of 1° C. could be easily read off. The bulb of this thermometer was placed into the sulcus between the extensor digitorum communis and the extensor carpi radialis brevis muscles, and retained in this position twenty minutes before the experiment commenced, during the passage of the

[1] Annales des Sciences naturelles. Zoologie. 2e série, vol. iii. p. 275.
[2] Müller's Archiv für Anatomie, etc. 1848, p. 144.
[3] Loc. cit. p. 90.

current, and some time after the current had ceased to act. In some of these experiments the skin was left bare, while in others both skin and bulb were covered with flannel. Certain sources of error are no doubt unavoidable in both modes of experimentation; since in the former the bulb will cool more quickly by being in contact with the atmosphere, while in the latter the normal loss of heat from the skin is to some degree prevented; nevertheless the results of the two series of observations agree on the whole so well, that the results which Ziemssen has obtained may be accepted without reserve. He caused the extensor muscles of the fore-arm to contract by applying the positive electrode of the faradic machine to the radial nerve, between the external condyle of the humerus and the insertion of the deltoid muscle, the negative electrode being fixed on the sternum. By acting in this way, the fore-arm, and more especially the skin covering the extensors, was not touched by the electrodes, so that there was no direct action of the current on the blood-vessels of the corium. It then appeared that the muscular contractions caused by faradisation of the motor nerve augment the temperature in the muscles animated by the latter and indirectly in the skin covering the same, without altering the colour of the skin or the calibre of its blood-vessels. The increase of heat is proportional in its extent to the energy and duration of the contractions. The person experimented upon perceives, during and after the experiment, a sensation of intense heat in the faradised muscles. The bulk of the latter is likewise increased, so that the fore-arm gains one-fourth to one-half inch, and the thigh one-half and even a whole inch in circumference. During the first minute the mercury fell from 0°·1 to 0°·5 C., but rose in the third minute and continued to rise afterwards. In one experiment the increase of heat amounted to 4°·4C. (7°·9 F.). If the skin and bulb were covered with flannel,

the temperature rose more quickly and to a higher degree than when the skin was bare. In both cases, however, the amount of heat produced was the same, and the apparent difference in the latter instance was due only to the exclusion of air from the faradised part, whereby the heat which was generated was longer preserved.

After the experiment there was a tendency towards equalisation of temperature within the system, so that the heat of the rectum and of the other colder organs rose at the expense of the greater heat of the muscles.

The decrease of temperature, after the faradic excitation had ceased, was slow and regular; and it was more rapid when the skin was exposed to the air than when it was covered.

In 1858, I made a number of experiments on the heat developed by electro-muscular contractions, especially on paralytic patients, which have led to the following conclusions:—

1. The heat observed after faradisation of the muscles is in no way due to the action of the current upon the skin. This we might theoretically infer from the fact that, even when the electrodes are in direct contact with the skin, a faradic current of moderate power applied by well-moistened directors does not act on the skin, but traverses it, and penetrates to the muscles; but the proposition is also established by an experiment I made in a patient suffering from lead-palsy. In that case the contractility of the extensor muscles of the *right* fore-arm was quite gone, while a certain amount of contractile power still remained in the corresponding muscles of the *left* fore-arm. On faradising for five minutes the extensors of the left fore-arm, the temperature was increased from 89° F. to 91°·5 F., while the same operation made in the same place of the right fore-arm did not produce any increase of heat; but, on the contrary, the

heat, which had been 87°·5 in the right fore-arm before the electricity was used, was only 86° F. afterwards; which was owing to the exposure of the skin to the air.

2. The increase of heat observed after faradisation of the muscles is not due to a greater supply of blood to the arteries and veins; for these are not expanded, but constricted by direct faradisation, and consequently contain less blood after having been acted upon than they do in their normal physiological condition.

3. But the increase of heat observed after faradisation of the muscles is owing to an augmentation of those chemical changes which are continually going on in the tissue of a muscle, and which constitutes its nutrition. The solid structure of a muscle is imbibed by a fluid, the composition of which is variable. The liquid taken from a muscle which has been at rest is neutral or feebly alkaline; but after faradisation it becomes acid, in consequence of an augmented absorption of oxygen and the formation of lactic acid. It is probable that this acid is afterwards neutralised in the system by the alkaline carbonates contained in the blood; lactate of soda being formed, and carbonic acid being set free.

On examining the quantity of oxygen absorbed, and carbonic acid exhaled, by the muscular substance of frogs' thighs which have been skinned and suspended in vessels filled with air or oxygen, it is found that if some of the muscles are faradised, and others not, the quantity of the gases absorbed and exhaled by the faradised muscles is more than double that absorbed and exhaled during the same time by the quiescent muscles. The same differences occur in the living muscles of man; since, by the augmentation of the chemical changes, the heat is increased, and more blood is attracted to the capillary vessels of the muscular substance, whereby the bulk of the muscles is augmented.

4. With regard to the influence of the direction of the current upon the increase of heat, I generally remarked a slight difference in favour of the *direct* current—moving from the centre to the periphery—in healthy muscles; and an equally slight difference in favour of the *inverse* current —moving from the periphery to the centre—in paralysed muscles. In such comparative experiments the current used was always of the same intensity, equally rapidly interrupted, and directed to the same muscles for the same length of time.

5. Respecting the more or less considerable rapidity of the shocks used, I observed that the heat was increased more quickly and to a higher degree, if a rapidly-interrupted current was employed, than if the intermittences were slow.

The relations between heat and muscular work have been further investigated by Béclard,[1] Solger,[2] Meyerstein and Thiry,[3] and Heidenhain.[4] The latter observer found that a single contraction of a frog's muscle, even after being separated from the body of the animal, gives rise to a slight increase of heat; and that, as the muscle becomes gradually exhausted, the development of heat is diminished. At a certain period the muscle may still be able to contract, but is unable to cause an increase of temperature. If the muscle is stimulated, but prevented from contracting, more heat is developed than if a muscle is similarly stimulated but allowed to contract; from which it appears that the heat developed is not due to friction; for if it were owing to that, the heat would be greater in the second case, while it is actually less. At first the temperature rises rapidly, and then more slowly, until a maximum is reached, after which

[1] Archives générales, etc. 1861, vol. xvii. p. 21.
[2] Studien des physiol. Instituts zu Breslau, 1862, p. 125.
[3] Zeitschrift für rationelle Medicin, vol. xx. p. 54.
[4] Mechanische Leistung, Wärme-Entwicklung, etc. Leipzig, 1864.

a gradual fall takes place. If the intensity of stimulation is augmented beyond that degree which causes the maximum of contraction, the heat developed is not greater than before.

Ziemssen has recently investigated this subject by the most delicate thermo-electric tests, and found all the results which were previously obtained fully corroborated.

Leyden[1] has shown, that when the cord of dogs is faradised, tetanic contractions of the muscles take place, which increase the heat of the blood by 5·2° C., as shown by the thermometer in the rectum. Billroth and Fick[2] state that, when the cord is faradised, the temperature of the tetanised muscles rises more rapidly than the temperature of the rectum, which, in the normal state, is higher than that of the muscles; and that the muscles then actually become hotter than the rectum and all the other organs of the body.

VI.—ACTION OF ELECTRICITY UPON THE SENTIENT NERVES.

Sparks taken from the common electrical machine while in action, produce a sharp pungent sensation in the skin. The discharge of a Leyden jar through the body causes a peculiar stunning sensation, known as the *electric shock*. If such a shock is very powerful, it may destroy sensation and consciousness altogether, especially if directed to the head or neck; but, unless the electricity is of very high tension, it does not cause a diminution of sensibility. Dr. Richardson[3] found that if shocks of slight or medium power from the jar were sent in rapid succession through the fingers, the last

[1] Virchow's Archiv, 1863, vol. xxvi. p. 538.

[2] Vierteljahrsschrift der naturforschenden Gesellschaft in Zürich, 1863, p. 427.

[3] Medical Times and Gazette, September 11, 1858.

was felt as severely as the first, and the fingers were afterwards as sensitive to the prick from the point of a lancet as they had been before.

The continuous current, when applied to a sentient nerve, causes a sensation of pricking and heat, resembling that produced by a mustard poultice, not only at its commencement and cessation, but the whole time that the circuit remains closed. The sensation produced by a gentle current is slight and not unpleasant, like that of a poultice made of meal with a slight addition of mustard; but a strong current gives rise to a severe burning pain. The sensations produced differ likewise according to the condition of the electrodes used; if these be dry, the feeling of heat predominates over that of pricking, and is very unpleasant when the current is strong; but if moistened conductors are employed, the sensation is not so unpleasant; and wherever there is a morbid increase of excitability in a nerve, the galvanic sensation is often termed 'pleasant' or 'delightful.' As a rule, the effect on the sentient nerves increases proportionately to the length of time during which the current is made to act, since the latter improves the conductivity of the skin and subjacent tissues (p. 222); but if the current be applied for a considerable length of time, viz. from twenty to thirty minutes, the sensations of pricking and heat gradually give way to a feeling of numbness.

Marianini[1] was the first to investigate the influence which the direction of the current, applied to sentient nerves, has on the production of the physiological effects; and he arrived at the conclusion that the sensation was strongest on making the inverse and on breaking the direct current; that is, just the reverse of what takes place when the motor nerves are galvanised; for muscular contractions are more

[1] 'Mémoire sur la secousse qu'éprouvent les animaux, etc.,' in Annales de Chimie et de Physique. Paris, 1829, vol. xl. p. 225.

easily produced on making the direct and on breaking the inverse current. Therefore, if mixed nerves are excited, the phenomena would be as follows:

Direct Current		Inverse Current	
Making	Breaking	Making	Breaking
Contraction	Sensation	Sensation	Contraction

The sensations produced by faradisation of the sentient nerves vary according to the tension of the electricity used, the rapidity with which the shocks succeed each other, and the condition of the conductors which are used for the transmission of the current. If the electricity be of low tension, it causes a slight pricking sensation; while if it be of high tension, intolerable pain is produced. A rapidly-interrupted volta-faradic current has more effect on the sentient nerves than a slowly interrupted one; because sentient nerves have the property of perceiving the effects of impressions some time after these have been made. If a sentient nerve in its normal condition be subjected to the action of a single and slight shock from an induction apparatus, the sensation caused by it is trifling; but if a second shock rapidly succeed the first, the sensation is more marked; because the nerve is no longer in its normal physiological condition when it receives the second shock, but in an excited state; a third shock has more effect than the second, and so on. If the velocity of the intermittences be very great, and the current sent for a certain length of time through the trunk of a nerve, a maximum of stimulation is reached; after which the sensibility of the nerve is diminished, and even falls below its normal standard.

Electrical anæsthesia.—The question whether surgical anæsthesia might be caused by electricity has, at various times, occupied the professional mind. It has been alleged

that teeth might be extracted without pain by the aid of galvanism, and that, in great surgical operations, electricity might be substituted for chloroform. Experience, however, has shown that no form of electricity can be used as a direct anæsthetic; and that when surgical operations are performed with the aid of electricity, the patient feels not only the pain of the operation, but also in addition to it the electric shock.

Dr. Richardson's researches on voltaic narcotism will be mentioned in a subsequent chapter; but I may say at once that electricity has no share in the production of that form of anæsthesia.

Although, therefore, electricity is no anæsthetic in the ordinary sense of the word, yet a considerable reduction of sensibility in a nerve may be accomplished by it. If a rapidly-interrupted faradic current of medium intensity be sent through the trunk of a nerve—say the ulnar, or the sciatic—by placing a moistened conductor connected with the positive pole to a point of the skin where the trunk of such a nerve is accessible, and another moistened director connected with the negative pole to the terminal branches of the nerve, and the action of the current be kept up for a quarter of an hour or more, the pain which is caused by this proceeding becomes much less after a time than it was at the beginning of the experiment, and a feeling of numbness is produced in the limb. The tension of the current may then be gradually increased to an enormous extent, without causing any inconvenience to the person experimented upon; while such electric power would at first have been unendurable. If the tension of the current be then again diminished, the person experimented upon appears to be quite insensible to shocks which had perhaps caused him much inconvenience previously.

Independently of the direction of the current, the negative

pole of a constant battery and of induction machines has a stronger effect on the sentient nerves of the skin than the positive pole. This circumstance may enable us to tell the direction of the current in an electrical apparatus, provided that certain precautions be taken. It is necessary, in the first place, that similar or nearly similar parts of the skin should be acted upon; since the epidermis is not of the same thickness in all parts of the body, and electricity is less strongly felt where the epidermis offers much resistance to its passage; moreover, the distribution of sentient nerves is not equal in all parts of the skin, and electricity is always felt more on parts which are richly endowed with nervous fibres, such as the face, than on parts which possess less abundant ramifications. It is also essential that the size and condition (moist or dry) of the conductors should be equal, since a current of the same power possesses more density if conveyed by a small electrode, than if transmitted by a conductor with large surface; and a moistened director will act less on the skin and more on the muscles, while a dry conductor will act more on the skin and less on the muscles. If, however, the precautions just described be taken, it is easy to distinguish the negative from the positive pole, by the stronger sensation caused by the former. It frequently happens that no sensation at all is produced by the application of the positive pole, and the negative pole is the only one that is felt. I have verified this fact on many patients, who have been able to tell the direction of the current, after they had been informed that the strongest sensation is produced at the negative pole.

The difference alluded to is especially remarkable if the feet of the patient are immersed in two basins filled with water and connected with the poles of the apparatus; in this instance the sensation is always stronger in that limb which is under the influence of the cathode. If the hands

are plunged into the basins, the effect is not quite so evident, as the epidermis of the right hand is generally thicker than that of the left, in consequence of the greater use habitually made of the right hand. If therefore the cathode be acting on the left hand, the sensation is stronger in the left than in the right hand; but if the cathode be directed to the right, the sensations are nearly the same in both hands, as the more powerful stimulus conveyed to the right hand is compensated by the greater resistance offered by its epidermis to the passage of the current.

There are sentient nerves not only in the skin, but also in the muscular tissue; and by faradising or galvanising the latter, a peculiar sensation is produced, which varies in strength according to the power of the current that is used. Duchenne has called this kind of sensibility 'electro-muscular sensibility.' Remak has denied that there is any such kind of sensibility; and Duchenne has certainly in some instances confounded it with the sensibility of the periosteum and perichondrium; yet there is no doubt that every electro-muscular contraction is accompanied by a special sensation, which exists independently of, and is quite different from, electro-cutaneous sensation.

VII.—ACTION OF ELECTRICITY UPON THE INHIBITORY NERVES.

Inhibitory nerves are those which, when irritated by mechanical, chemical, or electrical stimulants, arrest or inhibit the movements which are caused by stimulation of the motor nerves. Some physiologists being still inclined to doubt the existence of inhibitory nerves, it may be well to state at the outset that the existence of this particular set of nerves is indisputably proved by the following facts:—In woorarised animals, in which the motor nerve-fibres have

become completely paralysed, inhibitory effects may still be produced; while in atropised animals no inhibitory effects can be produced, although the motor and other nerves remain in their normal condition.

These nerves appear to have no specific histological qualities which distinguish them from other nerves; nor does it seem that the impulses which put them into action are specific; but their peculiar function is unquestionably owing to the arrangement of their peripheral termination.

Prof. Weber, who was the first to describe phenomena of inhibition, has also shown that inhibitory nerve-fibres do not go directly to the muscles, the action of which they inhibit, but that they enter into *controlling centres* or *inhibitory ganglia*, which rule the action of the muscles. We know now that in no case inhibitory nerve-fibres proceed directly to the muscular substance of the organs which they control, but that the influence of inhibition takes place indirectly, by the inhibitory nerves altering the energy of the motor ganglia. This is the reason why we find that inhibition is generally exercised, not upon individual muscles, but upon sets of muscles. The centres for these sets of muscles are distributed, in the shape of crowds of nerve-cells, in the cereoro-spinal centres and the peripheral nerves.

1 *Inhibitory nerves of the heart: the pneumogastric.*—Prof. Weber, of Leipzig, has discovered that irritation of one or both pneumogastric nerves, or of their centre, which is the medulla oblongata, may diminish or altogether arrest the heart's action. It had long been known that ligature or section of the same nerve accelerated the pulse; and the two kinds of experiments therefore appear to supplement and corroborate one another. Prof. Budge, of Greifswald, noticed the inhibitory effect of the pneumogastric nerve on the heart's action about the same time as, and independently of, Weber; and this subject has since

then been the favourite study of experimental physiologists, amongst whom Claude Bernard stands *facile princeps*. The latter observer has found that when the pneumogastric nerves are electrically irritated without having been previously divided, the action of the heart as well as the respiratory movements are arrested, and the eyes protrude; from which it appears that these nerves have at the same time a centripetal and a centrifugal action; and that after section of the nerves, faradisation of their central and peripheral ends produces altogether different effects.

Faradisation of the *central ends* causes the pupils to dilate and the eyes to protrude; on discontinuing the irritation, the eyes are drawn back into the orbs, and the pupils are contracted. The same proceeding has no effect upon the action of the heart, and if the current be gentle the respiratory movements also continue undisturbed; but if a strong current be used, the respiratory movements are arrested during inspiration, the blood in the carotid arteries becomes black, and a passive congestion of the mucous membrane of the mouth is produced; the tongue appears brownish-black, from momentary asphyxia, but the arteries continue to beat. As soon, however, as the current ceases to act, the respiratory movements recommence, and the velocity with which they succeed each other is then greater than it was before the experiment. Faradisation of the central ends of the vagi likewise causes sugar to appear in the blood, the cerebro-spinal liquid, and the bile, while the secretion of urine is arrested, and a flow of saliva observed; this latter being more viscid than that which is secreted on faradising the lingual nerve and the chorda tympani.

Faradisation of the *peripheral ends* of the vagi does not stop the respiratory movements, but arrests the pulsations of the heart and arteries, and generally causes vomiting.

That faradisation of the entire vagus and of its central end should produce diabetes, while a similar irritation of the peripheral end of the nerve should have no such effect, is, according to Cyon, owing to the circumstance that the former proceeding increases the inhibitory action of the nerve on the vaso-motor nerves of the liver. A powerful current produces complete paralysis of these vaso-motor nerves, and thus causes diabetes. When the pneumogastric is divided, we have the opposite condition, viz. unrestrained action of the vaso-motor nerves, and diminished production of sugar. It has been attempted to conclude from these observations that the beneficial effect of opium in diabetes is owing to its lessening the excitability of the pneumogastric.

Arloing and Tripier [1] have shown that there is a decided difference between the right and left nerve, inasmuch as the *right* acts more energetically on the *heart* than the left, while the *left* modifies the *respiratory movements* more profoundly than the right. They say that the heart's action is more completely arrested by faradisation of the peripheral end of the vagus than by irritation of the undivided nerve. Faradisation of the peripheral end arrests the heart's action during diastole, while irritation of the central end tends to to inhibit it during systole.

All the experiments hitherto described have been made with the induced current; but Prof. Donders [2] has lately made some important researches on the same subject with the aid of the constant current, and found that Pflüger's law obtains for this nerve as well as for the motor nerves; viz. that the establishment of catelectrotonus propagates in the nerve a stronger action than the disappearance of anelectrotonus. In these experiments he used a current of four cells

[1] Brown-Séquard's Archives de Physiologie, mars 1873, p. 175.

[2] Archives néerlandaises des sciences exactes et naturelles, tome vi. p. 328.

of Grove's battery, with unpolarisable electrodes; and registered on a revolving cylinder the pulsations of the heart by the application of König's stethoscope to the exterior of the cardiac region of rabbits previously shaved. Closing and opening of the circuit was produced in the same manner and with the same velocity by means of a chronoscope, with a tuning-fork making fifteen vibrations in the second. A descending movement of the platinum points dipped into mercury, so as to close the circuit, was made in 0·0104 of a second; and the ascending movement, which opened the circuit, was made in 0·0092 of a second.

The theory that the pneumogastric is an inhibitory nerve, has been combated by Schiff and Moleschott, who have endeavoured to show that the pneumogastric is the motor nerve of the heart, but that its energy is easily exhausted, even if it be only slightly irritated. Their reasoning has, however, as yet been unable to shake Weber's theory of inhibition, which is, amongst others, most strongly supported by Goltz's experiment, in which the frog's heart is caused to stand still during diastole by knocking the abdomen or the bowels of the animal with a spatula. The way in which the heart is reached in the experiment is as follows:—The stimulus conveyed by the blow reaches at first the sentient nerves of the abdomen; these carry the impressions to the spinal cord, from whence it travels upwards to the medulla oblongata. The origin of the vagus is now reached, and from these the heart's action is arrested. That such is really the case is shown by altering the conditions of the experiment. If the pneumogastric has been previously divided on both sides the abdomen may be knocked many times, yet no action on the heart is perceptible. Sudden death, after a blow or kick on the abdomen, or after the introduction of a catheter, may be explained by the results of this experiment.

2. *Inhibitory nerves of respiration: the superior laryn-*

geal nerve.—Prof. Rosenthal,[1] of Berlin, considers that the superior laryngeal nerve, which is given off from the lower end of the ganglion of the pneumogastric, has inhibitory effects upon the diaphragm, and arrests inspiration. He found that, by dividing the pair of nerves and then faradising their central ends, movements of deglutition occurred, and the diaphragm stood still. A very gentle current only diminished the respiratory movements; but on increasing the faradic power, the glottis was closed, respiration arrested, and the diaphragm relaxed. By a maximum of power the expiratory muscles were contracted. Just as faradisation of the pneumogastric arrests the heart's action, faradisation of the superior laryngeal arrests respiration. The same influence therefore, which determines movements of deglutition, protects the air-passages from the entrance of foreign bodies, by arresting temporarily the act of respiration.

All subsequent observers have corroborated the accuracy of Rosenthal's experiments, but Goltz and Schiff have given a different explanation of the same. They say that the superior laryngeal may have an inhibitory effect, but does not contain special inhibitory fibres; that faradisation of other sentient nerves will arrest respiration, and that such cessation of breathing is one of the commonest phenomena observed in animals during vivisections. The subject appears to require further elucidation.

3. *Inhibitory nerves of the blood-vessels: the depressor nerve.*—Ludwig and Cyon have discovered that a small nerve which arises from the superior laryngeal, possesses the property of dilating the blood-vessels and of diminishing the frequency of the pulse. This nerve runs along the carotid artery close by, but quite distinct from, the sympathetic,

[1] Die Athembewegungen und ihre Beziehungen zum Nervus vagus. Berlin, 1862.

and ends by uniting with branches of the ganglion stellatum, and forming a plexus between the aorta and the pulmonary artery. If this nerve be divided and its peripheral end faradised, no result is seen; but on faradising its central end, the pressure of blood in the vessels appears to diminish, not only in the carotids, but in remote branches of the aorta, the pulsations of the heart being at the same time retarded. If the experiment be continued for some time, the heart gradually resumes its previous action, showing that the effect on the heart and on the blood-vessels is not the same. The depressor nerve does not act by diminishing the force of the heart's action; for if the pneumogastric be divided, and the upper portion of the sympathetic in the dorsal region be removed, together with the ganglion stellatum and all its branches, faradisation of the central end of the depressor nerve still continues to cause a diminution of pressure in the blood-vessels. The depressor nerve diminishes the pressure of blood by affecting certain nervous centres for the muscular coats of the blood-vessels, which are situated in the brain.

4. *Inhibitory nerves of the intestines: the splanchnic nerves.*—In 1856 Pflüger[1] discovered that the splanchnic nerves have an inhibitory influence upon the movements of the intestines. Faradisation of these nerves, which take their rise from the six lower dorsal ganglia of the sympathetic, causes the peristaltic movements of the small intestines to be arrested. Prof. Lister,[2] who has experimented upon the same subject, inclines to the opinion that the inhibiting influence is only produced if a strong current be applied to the splanchnic nerves; but that there is an increase of

[1] Ueber das Hemmungs-Nervensystem für die peristaltischen Bewegungen der Gedärme. Berlin, 1856.

[2] Preliminary account, &c., in Proceedings of the Royal Society, Vol. i. No. 32.

function in them if they are acted upon by a gentle current. Biffi, Kupffer, and Ludwig have thrown doubts upon the accuracy of Pflüger's experiments; but if proper care be taken not to irritate any motor fibres at the same time, the experiment always succeeds.

Ludwig and Cyon have found that sections of the splanchnic nerves lowers the pressure in the vessels, while faradisation of their peripheral extremity increases it. After section of the splanchnic nerves faradisation of the depressor nerve has no effect; so that a close connection between these two nerves is rendered manifest.

VIII.—ACTION OF ELECTRICITY UPON THE HEART.

The phenomena produced by faradisation of the heart differ according to the parts of the organs which are acted upon. The heart receives its nervous supply from four sources; viz.: 1. The *sympathetic ganglia*, which are situated in the substance of the heart itself, and which, as Bidder and Rosenberger have shown, are found clustered together in the lines of junction between the auricles and ventricles, and between the auricles and the great veins; these impart to the heart the power of *beating rhythmically*. 2. The motor nerves, which from the *cervical sympathetic* send the motor impulse to the heart. 3. *Bezold's cardiac nervous centre* in the medulla oblongata; and 4. The *depressor nerve*.

Faradisation of the ventricle and the atrium of a frog's heart, which is still actively pulsating, causes the heart to contract, so that its movements may cease altogether; but on applying the electrodes to the bulbus aortæ, the pulsations become more powerful; they disappear entirely if the current be caused to act on the vena cava, and begin again after the cessation of the current. These differences may

be understood by remembering that some of the nerves of the heart impart to it motive power, and that faradisation of them augments the heart's action, while others regulate and inhibit its action; and that faradisation of these latter will arrest the work of the heart.

When after the death of an animal the heart has ceased to beat, and it is then faradically excited, pulsations become again perceptible, and these are more marked in the right than in the left ventricle. After death the *left* ventricle is generally firmly contracted, and insensible to the electric stimulus; the *right* ventricle, on the contrary, is almost always loaded with blood, and contracts powerfully when faradised. In animals killed by chloroform, sometimes the left ventricle continues to beat feebly, while the action of the right ventricle is arrested, from being distended by venous blood. Faradisation of the right side of the heart will then cause its pulsations to begin again, and the dilatation is at once lessened. Baron Humboldt has made some interesting experiments with frictional electricity on the heart of a carp which had been cut out of the body.[1] Immediately after that operation thirty-four pulsations occurred in the minute; the heart was then touched with a solution of protosulphide of potassium, after which the beats fell to nine. Five minutes after the heart had been removed there were only three pulsations in the minute. Feeble discharges from a jar were now directed to the substance of the heart, when the pulsations rose to twenty-eight; a somewhat stronger discharge was then administered, and the pulsations again fell to eight; a still stronger discharge entirely destroyed the contractility of the organ, and no further pulsations could be induced.

[1] Untersuchungen über die gereizte Muskel- und Nervenfaser. Posen and Berlin, 1797, vol. ii. p. 214.

The following experiment is described in the Report of the Committee on the Uses and Effects of Chloroform, instituted by the Royal Medical and Chirurgical Society.[1] In this experiment I administered the faradic current :—

'A large dog was made to inhale the mixture A (alcohol 1 part, chloroform 2 parts, ether 3 parts) by means of a towel. He became insensible at 2 min. 15 sec. The heart stopped at 10 min. 55 sec. Galvanism [faradism] was applied, the one pole to the needle in the heart, the other to the mucous membrane of the prepuce, the current being slight in force and interrupted. At 11 min. voluntary efforts at respiration commenced. These movements of respiration continued regularly till 11 min. 50 sec., when they ceased. During this period no galvanism was applied. The needle did not indicate any movement of the heart. Galvanism was then again employed, and at 13 min. 50 sec. the animal again commenced to breathe, and some movement of the heart was observed. At 15 min. 30 sec. the respiration was regular, the heart beating 140 per minute. The galvanism was gradually discontinued. At 18 min. the animal was breathing regularly. At 20 min. the cornea became sensible, and the animal recovered.'

Dr. Steiner,[2] of Vienna, has made some experiments in animals whose hearts had ceased to beat. He put the cathode on the prepuce or the vagina, and connected the anode with the needle in the heart; in other cases the negative electrode was put to the seventh insercostal space, the skin having first been injured to allow the transmission of the current. In six cases he succeeded in resuscitating the animals; in ten he was unsuccessful; but seven experiments with artificial respiration failed likewise.

[1] Medico-Chirurgical Transactions. London, 1864.
[2] Archiv für Chirurgie, vol. xii. 1871, p. 741.

IX.—ACTION OF ELECTRICITY UPON THE CONTRACTILE FIBRE-CELLS.

All forms of electricity have a marked action upon the muscular fibre-cells, but more especially so the induced current.

If an electric shock be applied to a voluntary muscle, it contracts, and then as quickly relaxes; while the movements induced by the application of electricity to the contractile fibre-cells do not occur simultaneously with it, but only some time afterwards. The only exception from this rule is made by the iris, which resembles in this respect the voluntary muscles. The motion once excited in the fibre-cells continues for some time after the cessation of the current, and is not confined to the parts to which the electricity has been directly applied, as is the case with the voluntary muscles, but is propagated to other portions of the same tract. It has, however, been shown by Helmholtz and Fick, that both the striped and unstriped fibres pass actually through the same periods of contraction; and that there is only a difference as regards the rapidity with which these latter succeed each other.

The continuous current causes contractions on closing the circuit, and while it remains closed. The power of the current employed, and the length of time during which its action is kept up, determine the intensity and duration of the movements.

It is an interesting fact that these contractions always take place in an order which corresponds to the physiological purpose; since by faradisation or galvanisation of the intestines, we can only cause peristaltic, but no anti-peristaltic contractions; if the uretheres are acted upon, the contraction proceeds from the kidneys to the bladder, but never in the opposite direction, whatever may be the intensity and the

direction of the current, and whatever may be the portion of the tract to which the electrodes have been applied.

The effects of electricity on the unstriped fibres have been investigated in living and dead animals, and in bodies of criminals after execution. Researches of the latter kind were chiefly undertaken by M. Nysten,[1] during the wholesale slaughter which accompanied the first French Revolution; and more recently by Henle, Kölliker, Gerlach, Harless, Onimus, and others. The results of these experiments are somewhat at variance with each other; which is no doubt due to the circumstance that some have employed the continous, and others the induced, current; and that those who have employed the continuous current have, in some instances, made use of very feeble batteries.

The Iris.

Faradisation of the iris causes a rapid change in the shape of the pupil, which ceases as soon as the current ceases to act. According as the radiating or circular fibres of the iris are affected, dilatation or constriction of the pupil ensues. The circular fibres are stimulated, and the pupil is constricted, if one electrode is directed to the centre of the cornea, and the other to any point of the head or face; or if one metal of a galvanic pair is placed in the nose and the other on the tongue. For the success of the latter experiment it is, however, necessary that it should be made in a room where only so much external light is admitted as is sufficient for discerning the size of the pupil. It is then easy to observe that the pupil contracts each time the metals are brought in contact with each other.

The radiating fibres of the iris are stimulated, and the

[1] Nouvelles expériences galvaniques faites sur les organes musculaires de l'homme et des animaux à sang rouge. Paris, an XI. (1803).

pupil becomes dilated if the galvanic or faradic current is directed to the edge of the cornea or to the sclerotica. On applying the electrodes to the upper and the lower part of the cornea, the pupil assumes the shape of a lying oval; and when they are placed to the right and left side of the cornea, the pupil takes the form of a standing oval.

Intestines.

The fibre-cells of the intestines respond readily to the galvanic and faradic stimulus. Aldini observed that when a zinc plate was introduced into the mouth, and a piece of silver into the rectum, of a recently-killed bullock, and both metals were connected by means of a wire, the abdominal muscles of the animal were convulsed and the fæces discharged. This experiment was repeated by M. Achard, of Berlin, on himself, who experienced, almost immediately after the circuit had been established, pain in the pelvis, and soon afterwards the bowels were voided of their contents.

By applying electricity to the *salivary glands* directly, no apparent effect is produced; but Professor Ludwig [1] has shown that faradisation of the lingual and auriculo-temporal nerves, the chorda tympani, and the posterior parotideal branches of the portio dura, causes an abundant flow of saliva. These nerves are therefore secretory nerves. Claude Bernard [2] states that faradisation of the nerves just named dilates the blood-vessels of the salivary glands, and that this dilatation of the blood-vessels is due to a greater attraction of arterial blood developed in the tissues; while faradisation of the sympathetic nerve arrests salivary secretion. The amount

[1] Lehrbuch der Physiologie des Menschen. Heidelberg, 1853. Vol. ii. p. 59.

[2] Journal de la Physiologie de l'Homme. Paris, Oct. 1858, p. 649.

of saliva which may be collected in a very short time from the salivary glands, if the nerves above named are faradised, by far surpasses the volume of the glands themselves, so that it cannot be supposed that the saliva is simply squeezed out of the gland; but it is secreted in the gland at the very moment when faradism acts on the secretory nerves. The excretion of the saliva is effected by the same forces which attract the blood to the glands, and not by the tissue of the glands, since the elementary substance of the glands has no inherent contractile power. Bernard is inclined to assume that the capillaries possess two properties, one of contraction and the other of dilatation; and that either of these properties is put into play by a peculiar set of nerves.

Faradisation of the *œsophagus* in man causes contraction of its longitudinal as well as of its circular fibres; and if the action of the current be kept up for a certain time, the contraction is no longer limited to the part directly operated upon, but proceeds downwards towards the stomach. In man and most of the mammalia, the œsophagus is composed of both striped and unstriped fibres, so that the aspect of its faradic contraction resembles neither that of voluntary muscles nor that of fibre-cells. In birds the œsophagus consists exclusively of unstriped fibres; the faradic motion in the œsophagus of birds therefore commences slowly and continues for some time after the cessation of the current. In the rodentia or gnawers the œsophagus consists of striped fibres only, and in them faradisation produces a rapid contraction, which ceases immediately with the cessation of the current.

The *stomach* responds to the electric stimulus by a shortening of both its longitudial and transverse diameter, the direction of the movement being always from the cardia to the pylorus.

The *small intestines* are particularly excitable to faradisation and galvanisation. On opening the abdominal cavity

of recently-killed animals, powerful contractions of the intestines are observed, owing to the contact of these tissues with the atmosphere. After a time these contractions cease and if the faradic current is then caused to act upon the small intestines, they again contract strongly, and the contents of the bowels are propelled towards the rectum. On placing the electrodes very near to each other at any point of the intestines, and shortly afterwards rapidly removing them, the canal becomes constricted in that portion to which the electrodes have been directed. This constriction reaches its maximum a short time after the electrodes have been removed, and then slowly disappears. It generally extends a little above and below the point where the electrodes have been placed, and is most striking in the duodenum, but not very marked in the cœcum. There is at the same time increased secretion of intestinal mucus. The *colon* and *rectum* respond to the electric stimulus, although not so readily as the small intestines. The contractions of the intestines may be studied during life in patients affected with hernia.

If the *gall-bladder* be acted upon by electricity, it is seen to contract and to void the bile into the duodenum. On placing the electrodes very near to each other, a constriction is produced in that organ which may be so strong as to divide it in two distinct parts which do not communicate with each other.

The *spleen* of most mammalia contracts fairly well under the influence of faradisation; but concerning the contractility of the human spleen there is much difference of opinion. Kölliker, Dittrich, and Gerlach[1] deny its contractility; while Wagner,[2] Harless,[3] and Claude Bernard

[1] Prager Vierteljahrsschrift, 1851. Vol. viii. p. 65.
[2] Jena'sche Annalen, 1849. Heft 1.
[3] Augsburger allg. Zeitung, 1850.

affirm it. This discrepancy is probably owing to the circumstance that Kölliker used a feeble continuous current, while Wagner and Bernard employed a powerful induction apparatus.

Chvostek[1] states that by faradisation of the skin over the spleen he has succeeded in considerably reducing tumours of the spleen arising from ague. Such a proceeding would, however, not act directly upon the substance of the spleen, but by reflex action from the sentient nerves of the skin on the splenic branches of the cœliac plexus. Mosler[2] and Landois have shown that after section of the nerves of the spleen in dogs, the organ swells up to such a bulk that the abdominal incision had to be enlarged in order to return the spleen into the abdominal cavity.

The *uretheres* respond readily to both kinds of current; they are at the same time shortened and constricted, and the contractions proceed in the direction from the kidneys to the bladder. These contractions continue long after the application of galvanism or faradism has ceased.

The *bladder* contracts vigorously when its muscular fibres are directly faradised; and it may also be caused to contract by faradisation of certain parts of the central nervous system.

Professor Budge has made some experiments on the mode in which the nervous influence is carried to the bladder; and found that by faradising the cerebral hemispheres, the corpora striata, and thalami optici, no effect was produced on that viscus; nor did any action become perceptible when the cerebellum was faradised. As soon, however, as the pedunculus cerebri and the restiform bodies were touched by the electrodes, the bladder was seen to contract, and urine was voided. Thus it was made evident

[1] Wiener Medic. Presse, No. 7, 1870.
[2] Mosler, Die Leukämie, p. 131.

that nervous fibres exist at a certain point in the upper portion of the cerebro-spinal axis, which have a special relation to the movements of the bladder.

Budge has likewise endeavoured to determine the course which these fibres take in order to reach the viscus, and which might lead either through the pneumogastric, the sympathetic nerve, or the spinal cord. Both the pneumogastric and sympathetic were divided without altering the phenomena previously observed; but, after section of the cord, faradisation of the parts just mentioned proved ineffectual. Further experiments showed that these motor fibres of the bladder proceed from the pedunculus and the restiform bodies through the anterior columns of the cord to the anterior roots of the third and fourth sacral nerves, and that their function may be excited both by cerebral influence and by reflex action, the latter through the intermediate agency of the posterior roots of the sacral nerves.

Besides the one just mentioned, there is another nervous centre for the bladder in the lower portion of the lumbar cord, faradisation of which causes well-marked movements of the viscus, and the excitability of which, after death, persists longer than that of any other portion of the cord in relation to the bladder. Motor nervous fibres proceed from this, independently of those first described, through the hypogastric plexus on their way to the bladder.

Another important result of Budge's researches has been, that the muscle hitherto described by anatomists as *sphincter of the bladder*, is no sphincter at all, physiologically speaking; and that the longitudinal as well as the circular unstriped muscular fibres of the bladder—that is, the muscles known as detrusor urinæ and sphincter vesicæ—serve exclusively for expelling the urine, without having the least effect in closing up the orifice of the viscus. Faradisation of any portion of the bladder causes urine to be voided;

and when Budge caused a column of water to flow in an uninterrupted stream out of the bladder, faradisation of the anatomical sphincter had no influence in arresting the flow. This was, however, immediately checked when the electrodes were directed to the membranous portion of the urethra, acting upon the constrictor urethræ and bulbo-cavernosus muscles. The nerves animating these muscles originate in the pedunculus cerebri, and emerge from the cord between the third and fifth sacral nerves, being enclosed in the sheath of the pudendal nerve. The muscles mentioned habitually close the bladder by means of their reflectory tone—a special arrangement to that effect existing between the posterior roots of the third, fourth, and fifth sacral nerves, the lower part of the spinal cord, and the anterior roots of the same sacral nerves.

The female bladder, has, likewise, no sphincter, properly speaking; but the constrictor vaginæ takes in females the place of the constrictor urethræ and bulbo-cavernosus muscles in males. If these researches were confirmed by subsequent observers, it would be best to drop the term sphincter of the bladder altogether, and to call the dense mass of unstriped circular fibres near the opening of the urethra into the bladder, the annulus circularis.

The vas deferens, the epididymis, and the tunica vaginalis propria, possess galvanic as well as faradic contractility.

Uterus.—Prof. Weber has observed contractions of the gravid and non-gravid uterus in bitches and rabbits. Dr. F. W. Mackenzie[1] noticed that this organ contracts more readily when the anode is directed to the spine and the cathode to the cervix uteri than when both electrodes are directly applied to its substance; and that the faradic current, directed longitudinally through the uterus, promotes powerful and general uterine contraction, whereas a current

[1] Medico-Chirurgical Transactions for 1859, p. 160.

passed transversely through the organ excites partial contractions only in the direction of the current. Dr. Mackenzie has stated that the faradic contraction of the uterus differs widely, by its slowness, from that of the other involuntary muscles when acted upon by electricity; but such is not the case, as the cœcum, the gall-bladder, and other involuntary muscles, respond equally slowly to faradisation as the uterus.

Opinions differ as to the precise seat of the nervous centre for uterine movements. Breschet and Longet found it in the lumbar portion of the cord; Budge thought it was the cerebellum; Drs. Tyler Smith and Snow Beck believed it was the sympathetic nerve; and Kilian accused the medulla oblongata. Th. Körner,[1] more liberal than his predecessors, attributed this function to the medulla oblongata, cerebellum, pons, corpora quadrigemina, crura cerebri ad pontem, corpus callosum, thalamus opticus, and corpus striatum. The last observer who has investigated these phenomena is Dr. W. Schlesinger,[2] of Vienna, who found that faradisation of the central end of a spinal nerve, in the rabbit, causes general and energetic uterine contractions within five to fifteen seconds. The uterus, which before the experiment is quite quiet, flabby, and has a pink colour, contracts to a hard pale lump; but when faradisation is discontinued, it becomes again pink and flabby These contractions Schlesinger looks upon as reflectory, as after section of the cervical cord the uterus does not respond to faradisation of a spinal nerve. He is inclined to think that the centre for uterine movements is in the medulla oblongata, and that the propagation of the stimulus to the uterus is affected not by way of the pneumogastric or sympathetic, but through the spinal cord.

[1] Studien des physiologischen Instituts zu Breslau. Heft 3.

[2] Medizinische Jahrbücher. Wien, 1873, p. 1.

The contractility of the *blood-vessels* is proportionate to the quantity of unstriped fibres they contain. It has been affirmed by Vassalli, Giulio, and Rossi that the *aorta* of man contracts when galvanised; but neither Nysten nor Kölliker have been able to perceive such contractions. The absence of contractility in the aorta is readily to be understood, if we consider that it consists almost entirely of elastic fibres, and contains only very few contractile elements, which, even when electrically excited, are not capable to counterbalance the elastic force which tends to keep the aorta open. Unstriped fibres are more abundant in the smaller arteries of man, and consequently these are seen to contract energetically when faradised. The aorta of horses, cows, and sheep contains more fibre-cells than the human aorta; and it is therefore probable that faradisation of it would cause contractions. The constriction produced in the smaller arteries of man when faradised does not occur immediately after the commencement of the current, but only after its action has been kept up for some time. When faradisation is discontinued, the constriction still increases for a short time, and then slowly disappears.

XI.—ACTION OF ELECTRICITY UPON THE BLOOD.

This subject has been already treated of under the heading of 'Electrolysis' (p. 42), to which the reader is referred. In this place I will therefore only mention some recent experiments made by Drs. Duncan and Fraser, of Edinburgh, with the view of discovering the exact effects of the continuous current on larger quantities of circulating blood than are present in healthy arteries, so as to show the effects produced in aneurismal sacs. For this purpose they endeavoured to produce artificial aneurisms in dogs by incisions into arteries; but, failing in this, they constructed an apparatus resembling an aneurism. This consisted of a glass

globe, capable of containing five ounces of blood, and which could be connected with an artery by means of tubes, and had also a contrivance for allowing the introduction and removal of the electrodes. They used this on the femoral artery of a large retriever mastiff, and found that after eight minutes there was not only spontaneous coagulation of the blood in the globe, but also electrolytic coagulation of both poles as usual. The position of the positive electrode was surrounded by a black ring, and beyond this there was a firm clot, with entangled gas-bubbles; while the position of the negative pole was surrounded by a quantity of froth intermingled with clotted blood. Both could be easily distinguished from the blood which had spontaneously coagulated, as it possessed greater consistence and tenacity than the latter. On dissecting the spontaneously formed clot, it was found that the electrolytic clots extended an inch into the mass, in a conical form; the negative had a diameter of 0·75 inch at the base, and a markedly alkaline reaction; while the positive was 0·5 inch at its base, and strongly acid.

The black coloration of the positive clot is probably owing to the action of nascent oxygen on hæmatine. The clots are blown out by the gas, which for the cure of aneurism is of importance, as their size is thereby increased. The negative pole would therefore appear to be at least as valuable as the positive. The mass of frothy substance is not so dense as the clot at the positive pole, but it is of sufficient consistence to remain undissolved for several days, and has the great advantage of being larger.

The microscopic alterations of the blood-corpuscles which are produced by the passage of the continuous current, have been minutely described by Rollet and Neumann;[1] but as

[1] Sitzungsberichte der Wiener Akademie, vol. xlvi., and Reichert and Dubois' Archiv, etc., 1865.

these phenomena have apparently only little scientific, and no practical importance, the reader interested in the same is referred to the original papers published by those two able observers. The same applies to the experiments of Dr. Golubew,[1] who has lately investigated the action of induction currents on the white blood-corpuscles, and to those of Dr. Burdon-Sanderson,[2] who has touched upon this subject in his lectures delivered in the Physiological Laboratory of University College.

XII.—ACTION OF ELECTRICITY UPON THE SKIN.

Sparks taken from the common electrical machine produce a sharp sensation in, and a peculiar eruption on, the skin, viz. a small circumscribed wheal which resembles lichen urticatus, and is surrounded by a little inflammatory blush. Frictional electricity applied to the scalp causes the hair to stand on end.

The effect of galvanism upon the skin is proportionate to the intensity of the current, the resistance offered to its passage, and the length of time during which its action is kept up. The kind of pain caused by the continuous current in the skin resembles that of burning, and is often compared to the sensation produced by a mustard poultice. This pain is very slight if the skin be dry, the current feeble, and the action short; but if the epidermis be moistened or previously removed by blisters, the effects are intensified. This latter circumstance was first pointed out by Baron Humboldt, in 1795. He had two blisters, each of the size of a crown, applied in the region of the two shoulder-blades, above the trapezius and deltoid muscles. On opening the vesicles, a serous uncoloured liquid was seen to flow out. The excoriated spots were then covered with a silver plate,

[1] Ibidem, vol. lvii. p. 552, 1868.
[2] Medical Times and Gazette, Jan. 7, 1871.

and as soon as a zinc plate was connected with it a liquid was seen to flow which had a reddish hue, and produced inflammation in those parts of the skin which were touched by it; at the same time, severe burning pain was experienced. Humboldt says that for several hours after this experiment he looked like a soldier who had been flogged. When the action of a feeble continuous current is kept up for hours, the skin and subjacent textures may be destroyed. A powerful current may cause rapid destruction, which is more extensive at the negative pole.

The effects of a single galvanic pair of zinc and silver directly applied to the skin are somewhat different from those of a pile applied by conductors. In the single pair the serum effused on the surface is decomposed, sodium being liberated at the silver, and chlorine at the zinc plate, thus forming chloride of zinc, the escharotic effect of which is well known. On the silver plate sodium is set free, which by oxidation rapidly becomes soda. Proceeding from these facts, Dr. Golding Bird has recommended the action of the zinc pole for establishing an electric moxa, for inducing a persistent discharge from some part of the body; and the opposite action of the silver plate has been used by Mr. Spencer Wells for promoting a rapid healing of torpid ulcers.

According to Remak, the anode relaxes the blood-vessels and reddens the skin, while the cathode, after a continuous application of from five to ten minutes, produces the opposite effect. On the anode there is a depression of the skin, while on the cathode a swelling of the epidermis and corium is produced.

Ziemssen[1] has found that relaxation of the muscular fibres of the skin and of the circular layer of the arteries, is more

[1] Loc. cit. p. 47.

quickly produced and lasts longer on the cathode than on the anode; while on the anode cutis anserina lasts longer, and is after a time followed by intense hyperæmia and the formation of papulæ. Hyperæmia and formation of papulæ is more extensive and intense at the cathode than at the anode.

The electrolytic effect on the skin is widely different on the anode and cathode. If the cathode be armed with a metallic conductor, a small vesicle is formed which after a time projects considerably beyond the surface. Its contents are found to consist of layers of epidermis imbibed with serum, and are strongly alkaline. After a time this serum assumes a brownish hue, and the vesicle is surrounded by an inflammatory areola. On the anode there is at first ischæmia, which is followed by the formation of a papula containing acid serum. The cathode is not altered, while the anode is oxidised. There is no increase of temperature. No chemical effects are perceived if unpolarisable electrodes are employed.

Hæmorrhage from the blood-vessels of the skin may follow a prolonged application of the current to the same. I have observed this in a patient, aged seventy-three, who was some years ago under my care for a severe form of neuralgia, which I treated by galvanisation of the cervical sympathetic nerve. As short applications did not appear to produce any result, I gradually prolonged the action to ten minutes at a time. After two such applications, the skin appeared to be diffusely reddened, both in the auriculo-maxillary fossa and at the cervical spine, but not more so than is often observed without leading to any further unusual appearances. In this case, however, the patient found, on both occasions, on taking off his collar in the evening, that it was soaked with blood, which must have come away during the day from the nape of the neck, but of the escape of which the patient had been

quite unaware, there having been no pain or any other feeling of discomfort during the discharge. It is evident that the dilatation of the blood-vessels which was produced by galvanisation must have gradually increased after the application to such an extent as to cause their rupture. Although this is the only case in which I have ever observed such a result, it ought to make us cautious with regard to prolonged applications, especially in old people. Possibly the senile condition of the arterioles may have favoured their rupture in this case.

Faradisation of the skin produces a pricking kind of pain, contraction of the muscular layer of the corium, and changes in the diameter of the blood-vessels. These effects are greater if the skin be dry than if it be moistened; for, if it be moist, the largest portion of the electricity is led off into the deeper structures; while, if it be dry, the resistance to passage is very considerable, and the skin itself receives almost all the electricity. A very powerful current, however, will affect both the skin and the more deeply-seated tissues.

Fick and Rosenthal have shown that faradisation by a comparatively weak current acts so much on the sentient nerves of the skin, because the current passing from the electrodes is divided into a number of rays, which encounter an enormous resistance to passage in the dry cuticle, and therefore only pass through it, where the epidermis is perforated by the ducts of the sebaceous follicles, and of the sudoriferous glands. The consequence of this is that each ray, on passing through such a better conducting substance, acquires more density, although that density is not sufficient for causing muscular contractions. Duchenne's wire-brush, which will be described in the third chapter, promotes this division of the current into a number of rays, and therefore causes a more thorough effect on the skin than an ordinary solid metallic conductor. The effects of faradism on the skin

are intensified by only just touching the skin with the wires, and not pressing them too firmly on it. By pressure, the transmission of the current to the more deeply-seated structures is promoted, and the skin is then proportionately less affected.

The effects of faradisation on the *blood-vessels* of the skin have been studied microscopically by Weber,[1] Max Schultze,[2] Kölliker,[3] and Pflüger.[4] They all agree that, at first, there is contraction, and afterwards dilatation of the smallest cutaneous vessels. This fact may be shown clinically by applying faradism by means of a fine wire-brush to the skin. We then see at first anæmia produced by spasmodic contraction of the arterioles, which is, after a few minutes, succeeded by erythema, owing to enlargement of the vessels; and if the tension of the current be very high, circumscribed wheals are produced, as by the application of frictional electricity. Faradism acts more immediately upon the vaso-motor nerves, the irritation of which causes at first contraction of the muscular fibres contained in the coats of the arterioles, and thus diminishes the calibre of the blood-vessels; this stage, however, is soon succeeded by secondary paralytic relaxation of the fibre-cells, and consequently increased calibre of the blood-vessels.

Erythema is more easily produced in women and in persons with a delicate skin; and is more marked at the negative than at the positive pole. On applying the thermometer, it is seen that simultaneously an increase of heat takes place, and this continues for some time after the application.

Faradism also acts on the contractile fibre-cells of the skin, and causes cutis anserina (goose flesh) from swelling of the hair follicles. Kölliker has observed this phenomenon on a piece of skin taken from the thigh of a recently executed

[1] Müller's Archiv, 1847, p. 232.
[2] De arteriarum structura. Gryphiae, 1849.
[3] Prager Vierteljahrsschrift, 1849. Bd. vi. Heft 1.
[4] Allgemeine mediz. Centralzeitung. 1855. Vol. xiv. August.

criminal, and Ziemssen on pieces of skin removed during surgical operations.

Such contractions are most powerful in the tunica dartos and the nipple ; the latter rapidly becomes erect, and remains so for some time after the cessation of the current. In other portions of the skin, however, the contractions do not last very long, but disappear more or less rapidly, and are followed by relaxation of the fibre-cells and erythema.

XIII.—ACTION OF ELECTRICITY UPON THE BONES.

An induced current applied, by means of moistened conductors, to bones which are only covered with skin, such as the frontal bone or the tibia, causes a peculiarly unpleasant sensation, from irritation of the sentient nerves of the periosteum. It is probable that, by applying electricity directly to the periosteum and the bones, a greater quantity of blood may be attracted to these parts ; but direct observations on this point are as yet wanting. Galvanism does not produce the same disagreeable sensation, when applied to the surface of the bones, as faradism.

CHAPTER. III.

MEDICAL ELECTRIC APPARATUS, AND METHODS OF USING IT.

In this chapter I shall describe the electric machines which may be used in medicine, and the methods by which the different forms of electricity have been, and are to be, therapeutically utilised. I shall speak at first of *Electrisation*, or the medical application of static electricity; after which I shall consider *Galvanisation*, or the application of the continuous galvanic current; and at last *Faradisation*, or the method of applying induction currents.

First principles of application.—Benedict[1] has laid down the general principle that, in using electricity or galvanism, care should be taken to apply it to the seat of the disease; and, if this should be impracticable, to direct it rather to a more central than to a more peripheral part of the body. Although I agree in the main with Benedict's proposition, I think it requires to be so far modified that, in a considerable proportion of cases, we should not only apply electricity to the seat of the disease (and which I term the *radical application*), but also to those more remote parts in which the symptoms are manifested (i.e. the *symptomatic application*). Thus, for instance, in the treatment of hemiplegia of the left side of the body from corpus striatum hæmorrhage, the only allowable application, according to Benedict's principle, would be to apply the electricity to the right cerebral hemisphere. Now, I am

[1] Electrotherapie, Wien, 1868, p. 73.

convinced that this is an effective method of treatment, and I rarely omit to use it in such cases; but I am equally satisfied that the progress towards recovery is far more rapid, if a peripheral or symptomatic application to the nerves and muscles of the paralysed extremities is combined with the central or radical application. What holds good for hemiplegia applies likewise to many forms of anæsthesia, hyperæsthesia, and other affections of the nervous system, which will be considered in the fifth chapter.

(A) Electrisation, Franklinisation, medical application of static, frictional, or Franklinic electricity.

I.—*History of it.*

The first who applied static or frictional electricity for medical purposes was a German physician, Dr. C. Kratzenstein,[1] Professor of Medicine at the University of Halle, who cured a patient of a contraction of the little finger, by sparks drawn from the ordinary electrical machine (1744). He also relieved another patient, who had two lame fingers, so far that he could again play on the harpsichord; and observed that the rate of pulsation was increased by the application of electricity. In 1748, M. Jallabert,[2] of Geneva, published a treatise on the effects of electricity upon the living body, and stated that electricity accelerated the pulse and increased the animal heat. He cured a locksmith, aged fifty-two, whose right arm had been paralysed by a blow from a hammer, within three months, by means of sparks and shocks; but this patient some time afterwards relapsed into his previous condition. M. Sauvages, of Montpelier, was, however, by the report of this case, induced to employ electricity

[1] Abhandlung von dem Nutzen der Electricität in der Arzney-Wissenschaft. Halle, 1745.

[2] Expériences sur l'Électricité, avec quelques conjectures. Paris, 1749.

in numerous cases of paralysis; and the report of the new remedy brought together such an enormous concourse of patients, that it was impossible to electrify them all sufficiently. The neighbouring populace, indeed, considered the cures which were made due to witchcraft, and the operators were obliged to have recourse to the priests to undeceive them.[1]

A few years later, Dr. Bohadtch, a Bohemian, communicated a treatise on medical electricity to the Royal Society, in which he contended that the remedy was chiefly of use in hemiplegia. In 1757, Mr. Patrick Brydone cured a hysterical woman in three days of general paralysis, from which she had suffered two years. Dr. Watson applied electricity successfully in the case of a girl, aged seven, who had for some time been in a state of catalepsy; and Dr. Edward Spry cured, by the same means, a girl, aged eighteen, of lockjaw and paralysis. On the other hand, cases were not wanting in which the remedy, being promiscuously and injudiciously employed, did no good, or even harm. The Abbé Nollet was honest enough to confess that, during a practice of fifteen or sixteen years, he had in no case produced any permanent beneficial effects. Dr. Hart, of Shrewsbury, paralysed a girl who was submitted to the treatment; and the paralysis was only removed by the use of medicines. The Abbé Mazeas caused epileptic fits in a person subject to that disorder, by electrifying him; and Franklin, to whom many paralytics resorted from all parts of Pennsylvania, could in no case effect any permanent good. He thought, however, that more advantage might have been obtained from the application of electricity if it had been accompanied with proper medicines and regimen, under the direction of a skilful physician.

[1] On the History and Present State of Electricity, by Joseph Priestly, 3rd edition. Two vols. London, 1775.—See also a paper on this subject by Mr. Donovan, in Dublin Quarterly Journal, 1846–47.

In 1778, M. Mauduit gave a highly-coloured account of the curative effects of electricity before the Société Royale de Médecine, at Paris; and it was chiefly in consequence of this report that the application of the machine in various diseases became for some time fashionable in the medical world. According to Mauduit, electricity is a stimulant; it increases the vital powers, attracts the blood to those parts of the body which are touched by it, and excites perspiration and even salivation, which frequently become very abundant if the electricity employed be of high tension. By the medical application of electricity obstinate pains are relieved, and the normal heat is restored to parts which have been cold for years; patients suffering from costiveness experience abundant evacuations; muscular atrophy, œdema, paralysis are cured, and tranquillity and sleep follow in due course. The pulse at the wrist is strengthened by positive, and retarded by negative electricity.

A few years later Cavallo recorded a number of observations in his essay on the theory and practice of medical electricity. He recommended the use of the electric machine for paralysis, weak sight, deafness, chorea, epilepsy, and for rescuing persons from trance. In 1802, M. Sigaud de la Fond elaborately described the different methods to be employed, and which are—the electric bath, drawing sparks, irroration, friction, insufflation, exhaustion, and commotion. If we were to believe M. Sigaud de la Fond, there is hardly a disease known in pathology that would resist the use of the electric machine.

After the discovery of the voltaic pile (1800), and especially after that of induction currents (1831), the medical use of frictional electricity was more or less abandoned; and it is only in the electricity-rooms of Guy's Hospital, under the superintendence of Drs. Golding Bird, Addison, and Sir William Gull, that therapeutical experi-

ments on a large scale have been undertaken with it. More recently static electricity again found a staunch advocate in Dr. Clemens, of Frankfort, who has undertaken the irksome task of curing with it nearly every disease; but, generally speaking, frictional electricity may be said to have disappeared from medical practice. This is especially due to the circumstance that a clumsy apparatus is required for its use; that the weather has a considerable influence on the action of the machine; that the dose of electricity cannot be exactly regulated, and that with frictional electricity we are obliged to act indiscriminately upon the different tissues, without being able to localise it in those parts which seem to require it more particularly.

I.—METHODS OF APPLYING STATIC ELECTRICITY.

The principal methods of applying static electricity, which are even at the present time now and then used, are the electric bath, electrisation by sparks, and shocks from the Leyden jar.

As to the form of the machine, it matters little whether a glass cylinder or a glass plate be employed. As a curiosity it may be mentioned that, in the last century, Signor Pivati,[1] of Venice, used glass cylinders filled with Peruvian balsam and various other medicines; and Dr. Giuseppe Bruni has recorded a case in which he employed a cylinder filled with a purgative, and the patient, after having been electrified, is said to have experienced the same effects as if he had swallowed the drug.

1. *The Electric Bath.*—The electro-positive bath is said to increase the vital forces, the electro-negative bath to diminish them. An *electro-positive* bath is given with the

[1] Lettere dell' Elettricità medica. Venice, 1747.

electricity accumulated upon the glass plate, care being taken that the negative electricity, which the cushions or rubbers acquire by friction, be lost in proportion as it is liberated. The cushions, between which the plate is turned, are therefore made to communicate with the ground by means of a metallic chain. The machine being in action, the patient is placed upon an insulating stool and takes hold of the prime conductor. The whole surface of the patient's body thus becomes charged with positive electricity, while the air surrounding it is rendered negative. If the electric bath be given in a dark room, luminous appearances are produced by the escape of electricity into the air, especially about the hair and the eyelashes. It is said that during the discharge heat is evolved, circulation quickened, and the secretions, especially perspiration, become more active; but it is very doubtful whether these are constant physiological effects of the bath; probably they are merely caused by the excited imagination of the patient. The bath has been much recommended for improving the function of the skin and of the mucous membranes, and the patient ought to sit in it for about three hours a day.

The *electro-negative* bath is given with the negative electricity acquired by the cushions, while the positive electricity, which accumulates upon the glass plate, is dispersed in proportion as it is liberated. The cushions must therefore be insulated by means of glass supports, and the conductor upon which the positive electricity is liberated is connected with the ground. The electro-negative bath is said to have a lowering effect in reducing the natural electricity of the patient, so that the body is left without its normal stimulus; it is therefore believed to act like blood-letting, and to retard the pulse at the wrist. It has been recommended for erysipelas and chronic inflammations of every kind; for headache and different forms of neuralgia; but it has not

been proved that any constant physiological or therapeutical effects are produced by it.

2. *Electrisation by Sparks.*—If a patient be sitting in an electro-positive bath, and the hand of the operator be brought sufficiently near the patient's body, it becomes negative; and the negative fluid then combines with the positive electricity of the patient's body, whereby a flash of light is produced, together with a peculiar snapping noise, which forms the electric spark. Sparks may also be drawn from the body by approaching metallic conductors to any part of it. These sparks produce a pricking or pungent sensation, at the points touched; and if the proceeding be continued for some time, the skin becomes reddened, and white circumscribed wheals are produced. This eruption is more perceptible in persons with a delicate skin; the time necessary for its production varies in different people from five to ten minutes; and it generally disappears within an hour from its production. In the electricity-room of Guy's Hospital sparks were usually taken from the spine in the following way:—A brass ball, attached to a wire or chain, in connection with the ground, was passed up and down in the direction of the spine at a distance of about an inch from the surface. The patient being on an insulating stool, sparks passed from him to the brass ball, and thence escaped through the wire or chain to the ground. In this manner a rapid succession of sparks could be obtained, which acted like instantaneous electric currents. Cavallo has recommended to draw sparks through flannel; the patient sits on the insulating stool, as usual, and takes hold of the prime conductor of the machine; a piece of flannel is placed over the part which is to be electrified, and the knob of an insulated conductor placed in close contact with the flannel, and moved steadily down the part affected, so as to draw a large number of sparks in the direction of the ramifications of the nerves.

If sparks succeed each other rapidly, they produce slight vibrations in the superficial muscles. Electrisation by sparks has been much used for paralysis, and other affections of the nervous system; and in certain spasmodic disorders and some forms of amenorrhœa, it has proved decidedly useful.

3. *The Leyden Jar* (p. 8) was formerly much employed in the treatment of amenorrhœa and aphonia, and in such cases it was discharged through the pelvis or the throat. Dr. Golding Bird states that he has cured many cases of amenorrhœa by this means; but Dr. Wilks,[1] likewise Physician to Guy's Hospital, thinks it very questionable whether the discharge of the Leyden jar was of any value in amenorrhœa. As regards its use in aphonia, it no doubt cured many cases of the hysterical form of the complaint; but this result could not be attributed to any special quality of electricity, seeing that a good slap in the face would have been equally beneficial.

M. Beckensteiner[2] has recommended to 'animalise' static electricity through the interposition of the body of the operator, before applying it to a patient; and is of opinion that the Pacinian corpuscles play a considerable part in this animalisation of electricity! The operator touches the conductor of the machine with one hand, and rubs or shampoos the patient with the other; in some cases it is found sufficient to make simple passes, without touching the patient at all. M. Beckensteiner believes that the metals become 'etherealised' by the electricity which passes through them. According to him conductors of gold, silver, iron, antimony, zinc, tin and lead, have all a special action of their own on the body, independently of the electricity they convey; but conductors of gold are, on the whole, the best. He says that he can, by means of static electricity,

[1] British Medical Journal, Jan. 11, 1873.
[2] Études sur l'Électricité. Paris, 1859.

introduce iodine, valerian, musk, and assafœtida into the human system. Electrical mysticism has at all times found devoted adherents, and it is said that M. Beckensteiner's theories are acted upon at Paris, London, and Rome; if so, they will not do much harm.

A more important attempt to re-introduce static electricity into medical practice has been made by Prof. Schwanda,[1] of Vienna. He does not use the old-fashioned friction apparatus, but Holtz's electrophorus machine (p. 17), and says that the electricity yielded by it has the same effects in paralytic conditions as the induced current; that for anæsthesia of the skin it is better than either galvanism or faradism; and that it is useful in passive hyperæmia and swelling of the integument. Moreover the air is rapidly ozonised by means of it, and this alone is perhaps of use in certain pathological conditions. General effects of the application are increased heat and perspiration, and improved appetite.

Dr. Wilks[2] is of opinion that frictional electricity was not 'successfully superseded' by faradisation. He found that the application of the faradic currrent to the back was not productive of the same good as the withdrawal of sparks from the same region of the body; that patients suffering from paraplegia, who are now benefited by the constant current, were previously cured by frictional electricity; and that the latter has more effect in arousing the dormant nervous centres than faradism. This opinion, coming from so accurate an observer, is worthy of consideration; but we hardly think that Dr. Wilks would for this reason re-introduce frictional electricity into practice; for although it may in some respects have been superior to faradism, yet it is vastly inferior to the constant current.

[1] Medicinische Jahrbücher, 1868, Heft 3; and Poggendorff's Annalen, vol. cxxxiii. p. 126.

[2] Loc. cit. p. 21.

(B) GALVANISATION. I. *History of it.*—Galvanism was discovered in 1786, and made known in 1791. Its medical application was soon afterwards (1792) recommended by Drs. Behrend and Creve for distinguishing real death from apparent death or trance. Soemmering proposed that, in such instances, the galvanic current should be applied to the phrenic nerve. Valli succeeded in reviving, by means of it, frogs which had been all but suffocated in vessels filled with hydrogen, and fowls which were apparently dead from drowning. Hufeland, Pfaff, Reil, Baron Humboldt, and other German philosophers and physicians, strongly recommended the use of galvanism for the cure of disease, without, however, having employed it themselves in medical practice.

The first therapeutical experiments on patients were made at the University Hospital of Jena, with the current of a single pair, under the supervision of Prof. Loder, without any appreciable result. But, after the discovery of the voltaic pile (1800), experiments of this kind were again taken up by Drs. Bischoff and Liechtenstein, who have recorded the cure of two cases of amaurosis and the amelioration of a case of hemiplegia. The first systematical treatise published on the remedial powers of galvanism is from the pen of Dr. Grapengiesser, of Berlin (1801). He recommended the use of it in weak sight and amaurosis, in deafness, certain paralytic conditions, aphonia, tumor albus, rheumatism, and sciatica. In palsies he applied the direct current, placing the positive pole on the trunk of the nerve, and the negative lower down; and he also used basins filled with water, in which the directors, and the feet or hands of the patient, were immersed. In all other diseases he first vesicated the skin with cantharides, in order to diminish the resistance to the passage of the current. A few years later, Drs. Jacobi and Augustin published treatises on galvanism

as a remedial agent, and recommended to moisten the skin before the application, in order to facilitate the transmission of the galvanic fluid. The most celebrated of the earlier works on this subject is, however, by Galvani's nephew and pupil, Aldini,[1] of Bologna, who recommended the new remedy for diseases of the organs of special sense, for disorders of the mind, and many other neuroses. The physical, chemical, and physiological properties of galvanism, as they became successively known in course of time, excited the imagination of physicians and laymen in an equally powerful manner; and it was concluded that so marvellous an agent must needs possess extraordinary curative effects. It is difficult at the present time to imagine the enthusiasm, bordering on intoxication, for the newly-discovered remedial agent, which reigned in the commencement of the present century, and the unbounded expectations which were entertained as to its therapeutical value. It was not only recommended and used for the cure of all diseases, but was believed to be able to rescue from death persons who had been hanged or drowned.

Of the physiological action of the galvanic current upon the different tissues of the human body only little was known. The voltaic pile was indiscriminately and injudiciously applied, and much harm done with it. The power of this apparatus is, for reasons which have already been given (p. 24), very variable, and after a time entirely disappears, so that there was sometimes no current at all, while at others there was either a weak or a very strong current, and, by the use of the latter, accidents of a serious character, such as fainting fits, blindness, &c., were produced. It was also found very troublesome and expensive to

[1] Essai théorique et expérimental sur le galvanisme. Paris, 1804.

maintain the pile in a state of efficiency; and seeing all this, we need not be surprised that the confidence in the curative powers of galvanism was soon thoroughly shaken, and the voltaic pile degraded to the rank of talismans, amulets, animal magnetism, and mesmerism, thus forming part of the curative treasures of charlatans.

Further physical and physiological discoveries on the nature and properties of galvanism were evidently necessary before it could be employed with a fair chance of success in the treatment of disease. After a dead interval of thirty years, the physiological part of the subject was more thoroughly taken up in Italy, especially by Nobili, Marianini, and Matteucci; while Becquerel in France, Daniell and Grove in England, and Bunsen in Germany, invented galvanic batteries which furnished a more constant current, and one, therefore, more useful for medical purposes than that yielded by the original voltaic pile.

In 1825, M. Sarlandière,[1] who had often witnessed the beneficial effects of acupuncture in certain diseases, recommended to combine the application of electricity with acupuncture (electro-puncture). Sarlandière is generally mentioned as the inventor of *galvano-puncture*, but he used only frictional electricity, and not galvanism. Galvano-puncture was probably first used by Fabré-Palaprat,[2] who translated La Beaume's[3] unreliable treatise, and added to it fantastic dogmas of his own. A more scientific use of galvanism was made by Magendie, who from 1830 to 1840 used this agent in many cases with considerable success,

[1] Mémoires sur l'électro-puncture considérée comme moyen nouveau de traiter efficacement la goutte, les rhumatismes et les affections nerveuses, et sur l'emploi du moxa japonais en France. Paris, 1825.

[2] Du galvanisme appliqué à la médecine. Paris, 1828.

[3] On Galvanism, with Observations on its Chymical Properties and Medical Efficacy in Chronic Diseases. London, 1826.

employing chiefly galvano-puncture. During the next twenty years the surgical applications of galvanism were chiefly studied and practised. Gerard and Pravaz, seeing that the blood could be coagulated by the galvanic current, proposed to utilise this discovery for the cure of aneurisms; Mr. Liston was the first to use galvano-puncture in a case of this kind, and M. Ciniselli the first who did so successfully. As it had been shown that wires should be rendered incandescent by voltaic electricity, Steinheil, Mr. Marshall, Prof. Middledorff, and M. Amussat, used the galvanic cautery for the treatment of a number of surgical diseases. Prévost and Dumas, Bonnet, and Dr. Bence Jones, succeeded in decomposing urinary calculi by the continuous current, and Mr. Spencer Wells applied the same agent for promoting the growth of healthy granulations and the cicatrisation of ulcers.

To Prof. Remak,[1] of Berlin, the merit is due of having once more roused the attention of the profession to the use of the continuous current in nervous and muscular affections, and having shown that, if properly applied, it may produce beneficial effects in diseases of the nervous centres and of the sympathetic system of nerves. The singularly objectionable manner in which Remak brought forward his discoveries did much to discredit his writings and damage his reputation; but, within the last few years, a great reaction in favour of Remak's ideas has set in, and many of his apparently most reckless assertions have, by accumulated experience, been shown to be correct. This better appreciation of Remak's discoveries, and the re-introduction of the continuous current into medical practice, has been chiefly due to the labours of M. Benedict,[2] of Vienna, M.

[1] Galvanotherapie der Nerven- und Muskelkrankheiten. Berlin, 1858. And Application du courant constant au traitement des névroses. Paris, 1865.

[2] Electrotherapie. Vienna, 1868. And many papers in Austrian and German journals.

Moritz Meyer,[1] of Berlin, and the author of the present treatise.[2] The author has likewise endeavoured to introduce the scientific use of the electrolytic effects of the continuous current into surgical practice.[3]

II.—MEDICAL APPLICATION OF THE CONTINUOUS CURRENT.

Under this head I shall describe both the apparatus and the methods of applying galvanism in those diseases which fall within the province of the physician; while the galvanic cautery and the electrolytic treatment of surgical diseases will be considered in a subsequent section.

1. *Batteries furnishing a Continuous Galvanic Current.*—I consider the following requisites indispensable for machines of this kind. (1) They should furnish a large quantity of electricity. (2) The current should not be subjected to any considerable variations within a certain time (say one or two months). (3) The apparatus should be handy and fit for use in the consulting and sick room (vapours of nitric acid being particularly objectionable). (4) The number of cells should be considerable, so as to allow the dose of electricity to be given in an individual case to be exactly adapted to the nature of the malady and the constitution of the patient. The batteries which are now in use are partly constant, and partly inconstant. The use of the latter can at present be only excused if doctor and patient live at a great distance from the centres of

[1] Die Electricität in ihrer Anwendung auf practische Medicin. 3rd edition. Berlin, 1868.

[2] On the Value of Galvanism and Electro-Magnetism in Medicine and Surgery. London, 1868; and many papers in the Lancet, Medical Times and Gazette, and other journals.

[3] On the Electrolytic Treatment of Tumours and other Surgical Diseases. London, 1867.

civilisation. They must, however, be described, because the practitioner is often consulted about the advisability or not of using them.

a. *Inconstant Batteries.*—The original voltaic pile has entirely disappeared from medical practice, as it is not only unreliable, but also very troublesome to keep in order.

A new modification of the old voltaic pile has lately been recommended by Prof. Hammond,[1] of New York. In this instrument the copper and zinc plates are perforated, and soldered together. At the bottom of the pile is a plate of hard india-rubber, upon which is placed a pair of copper and zinc, with a copper wire soldered to the copper plate; upon this pair is laid a piece of flannel or woollen cloth, equal in size to the pair; then follows another pair, another piece of flannel, and so on. The pairs are so placed that the copper is always below. Another copper wire is soldered to the zinc plate of the last pair. For putting the machine into action strong vinegar is poured on the top; this passes through the pairs and moistens the flannel; a saucer underneath receives the excess of the vinegar. On the top of the instrument are two other plates of india-rubber, having each a large hole in the centre, and four holes for an equal number of hard india-rubber rods, by which the instrument is suspended on an iron or brass support. Insulated wires are used to connect the poles with the electrodes. This instrument is better than the original voltaic pile, but vastly inferior to the batteries of Daniell, Smee, and Bunsen.

Another modification of the voltaic pile, which was much used some time ago, is *Cruikshank's battery.* It has the advantage of being easily manipulated, but its current is as inconstant as that of the old pile. It consists of plates

[1] Quarterly Journal of Psychological Medicine, etc. July, 1867. Vol. i. p. 62.

of copper and zinc, which are arranged in wooden troughs. One trough generally contains fifty pairs, so that two troughs furnish a powerful current. To excite the battery, water, salt water, or acidulated water, is used: if distilled water be employed, the chemical action is feeble; but with acidulated water it is considerably intensified.

Cruikshank's battery was a decided improvement on the old pile, but is now completely superseded by more convenient and reliable instruments.

Wollaston's battery has the advantage that the pairs of

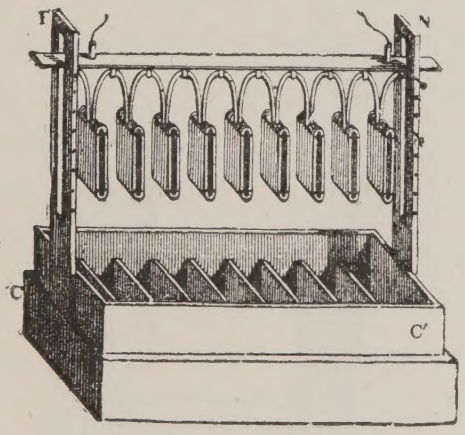

FIG. 49.—Wollaston's Battery.

copper and zinc can be easily immersed in, and withdrawn from, the exciting liquid; but the current furnished by it is likewise inconstant.

Amongst the portable modifications of the old voltaic pile, the instruments of Récamier, Pulvermacher, Breton, and Prudhomme, deserve special mention.

Récamier's Galvanic Poultice consists of pieces of cotton-wool, which contain minute pieces of zinc and copper, each pair being separated by a piece of flannel. The wool is placed in a bag, one surface of which is made air-tight and impermeable (of gutta-percha), while the other is of cotton. The permeable surface of the bag is applied to the skin and fixed by a binder; the impermeable side retains the

perspiration, which soon accumulates in a liquid state and causes the pile to act. The effect is more powerful if the flannel be wetted with vinegar. One of these poultices, bound tightly to the skin, produces a sensation of warmth; two of them cause a pricking sensation, and redden the skin. The apparatus was recommended to be worn day and night, and is said to have been used with benefit in cases of amenorrhœa, rheumatism, &c.

Pulvermacher's Galvanic Chains consist of a more or less considerable number of pairs, forming a little voltaic pile;

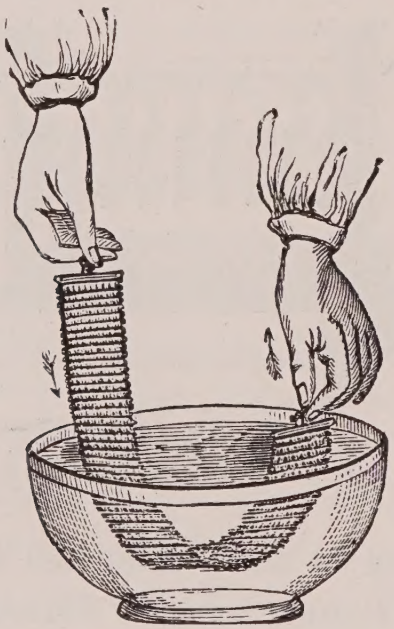

FIG. 50.

these pairs have a small surface, and the apparatus consequently furnishes a comparatively small quantity of electricity, but which possesses a high tension. Each pair of the original chain consists of a piece of wood, round which are coiled a zinc wire and a brass wire; each wire terminates in a ring, by which it is connected with the heterogeneous wire of the next link, that is, the zinc with the brass, and the brass with the zinc. At one end of the chain the zinc wire is free, forming the positive pole; at the other end the brass

wire is free, forming the negative pole. If the chains be immersed in vinegar, the wood is impregated with it and serves as a moist conductor, thus exciting the action of the battery.

Pulvermacher has frequently modified the construction of these chains, and lately done away with the wood, using merely a hollow cylinder of zinc, round which the brass is coiled. This has the advantage of allowing the zinc to be replaced when it has been destroyed by the chemical action of the battery. The chains are portable, handy, and easily put in action; but they have the drawback inherent to all modifications of the original pile, viz. that the current generated by them is liable to great and sudden variations within a short time. Moreover, in consequence of their small surface and high tension, they are not suitable for being applied to the nervous centres. A prolonged use of the chains, which is generally recommended, is not only opposed to all principles of physiology and therapeutics, but also condemned by daily experience; as, when thus employed, they cause sloughs, the cicatrices of which remain throughout life, and may aggravate the disorder for the relief of which they were brought into play.

Messrs. Breton Frères, of Paris, have constructed a *Galvanic Belt*, consisting of zinc and copper plates, which are separated from each other by a moist mastic; it furnishes very little electricity. *Breton's Electric Mixture* consists of two pastes, one of which contains zinc and the other copper in a pulverised state, mixed with sawdust and chloride of calcium, in order to keep it moist.

Innumerable varieties of galvanic belts and similar portable machines have since then been constructed, but which it is not necessary to describe. The only one which appears to give a somewhat constant current is Prudhomme's

modification of Marié-Davy's sulphate of lead battery (p. 32).

This consists of a disc of zinc of the size of a two-shilling piece, a ring of pasteboard, the interior of which is filled up with a paste of sulphate of lead, and a thin disc of copper. Any number of such pairs may be connected so as to form a belt, which, according to Prudhomme, preserves its efficacy for four or five days.

b. *Constant Batteries.*—Most constant batteries now in use are modifications of Daniell's, Bunsen's, and Smee's pair; while Grove's arrangement has, on account of its high price, the difficulty of managing it, and the necessity of using nitric acid for its charge, disappeared from medical practice.

Remak's apparatus (Fig. 51) consists essentially of four parts, viz. the battery B, the dial for regulating the power of the current S, a commutator or current-reverser C, and a galvanometer, for showing the condition of the battery G. The battery consists of sixty pairs of Siemens and Halske's modification of Daniell's pair, viz. zinc and copper, with water and a concentrated solution of sulphate of copper. Each of these pairs is, by means of telegraph wires, connected with the dial, the commutator, and the galvanometer. The dial is furnished with two sets of five studs each, standing in a semicircle. One of these is marked 2, 4, 6, 8, 10, and the other 10, 20, 30, 40, 50. In the middle of each semicircle is fixed a hand-plate, B_1, B_2, which may be turned so as to touch any of the metallic studs. B_1 gives a current of from two to ten pairs, while B_2 yields the same of from ten to fifty. If, for instance, a current of eight cells is desired, the hand-plate B_1 is placed to the stud 8, while B_2 is made to touch the board marked 0. If it is intended to use 26 cells, B_1 is made to touch 6, and B_2 put on 20, and so on. If both B_1 and B_2 touch 0, there is no current at all.

The conducting wires are connected with the binding-screws, K, copper, and Z, zinc. If the hand-plate of the commu-

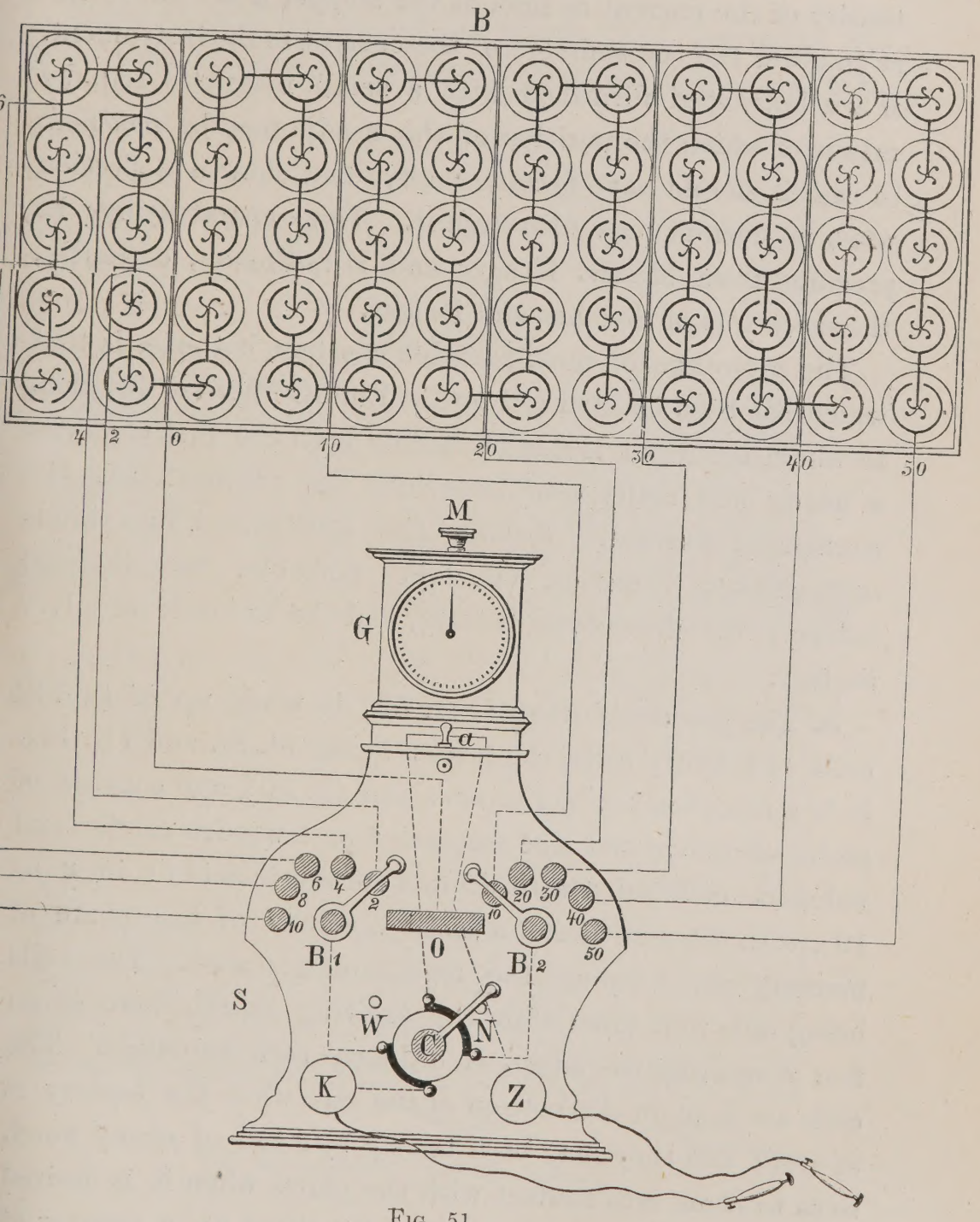

Fig. 51.

tator, C, marks N, the positive current travels through K into the human body, and through Z to the negative pole of the

battery; but if the hand-plate marks W, the direction of the current is reversed. The galvanometer, G, shows the intensity of the current as soon as the stopper *a* is removed, so as to allow the transmission of the current to the instrument. M is a brass stud furnished with a small magnetic rod, by means of which the position of the needle may be rectified, in case it should have become faulty, and show a deflection when no current passes through it. This apparatus may be procured from Messrs. Krüger and Hirschmann, of Berlin, the successors of Siemens and Halske.

The prototype of most portable constant batteries is that which has been constructed by Dr. Emil Stöhrer, of Dresden, to whom the merit is due of having been the first to devise a handy and really useful machine for administering the continuous current. Stöhrer has constructed four kinds of constant batteries, viz. the portable, the hospital battery, the electrolytic battery, and the chloride of silver battery.

a. The *portable battery* (Fig. 52) is made up of twenty cells and thirty cells, the prices being 8*l.* 8*s.* and 11*l.* 11*s.* It is a modification of Bunsen's pair (p. 30), and consists of plates of carbon and zinc suspended on a wooden carrier, and vulcanite cells filled with diluted sulphuric acid (1 in 8 or 10), with the addition of a small quantity of bisulphate of mercury for keeping the zincs amalgamated. The cells being only half filled with the exciting liquid, there is no fear of spoiling the latter, if ordinary care be taken. The cells are kept on the bottom of the case when the battery is at rest; and they may be lifted up by a rod of ebony wood, so as to come into contact with the plates when it is desired to use the battery. When the rod is lifted up, a quarter of a turn given to it places it horizontally, and keeps the cells suspended. All this time, the current is circulating. At the end of the application, another turn is given to the

black rod, and the cells are lowered again, so as to disconnect them from the plates.

Those parts of the battery on which chief ingenuity has been expended, and which have been extensively copied both

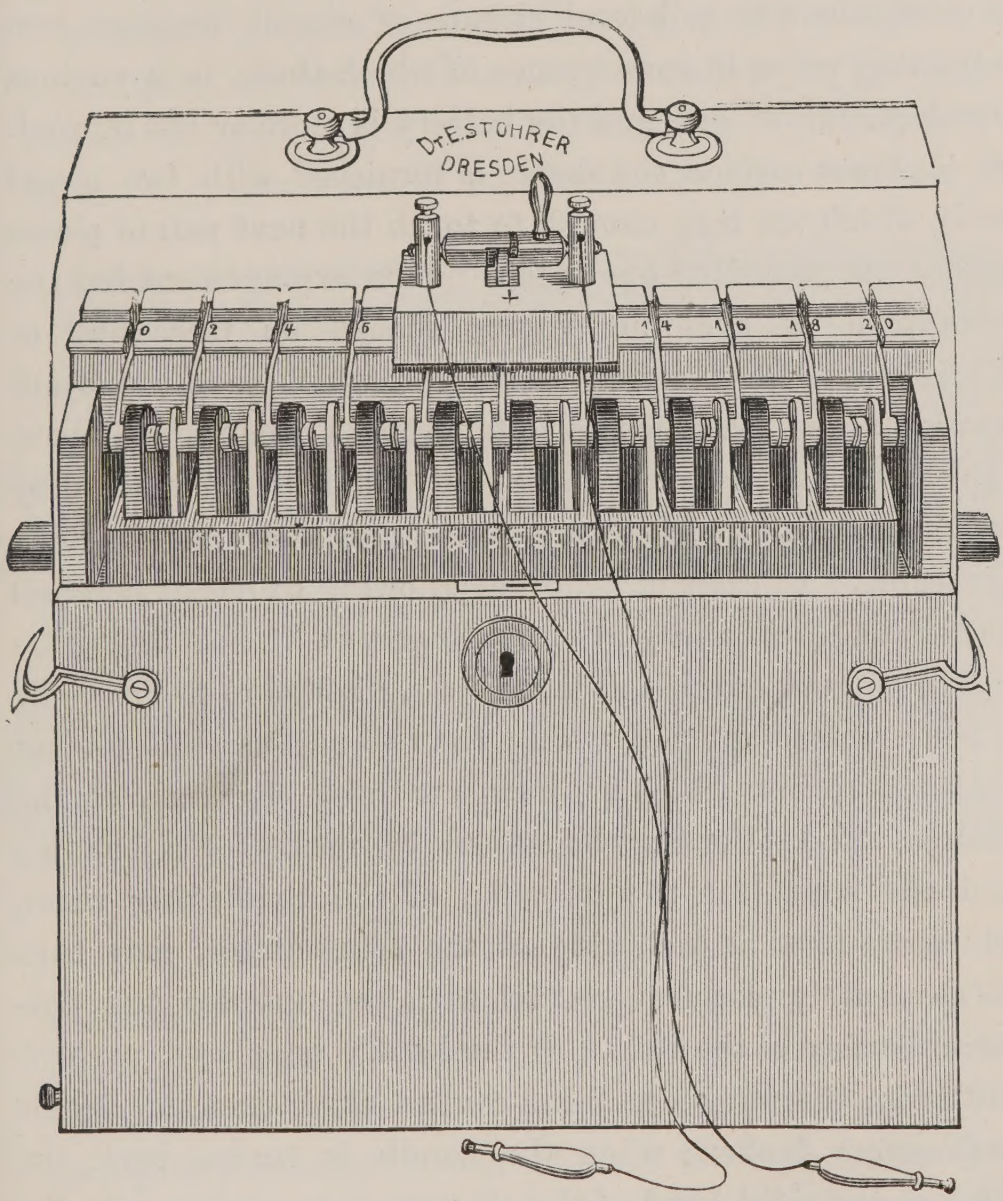

FIG. 52.—Stöhrer's Portable Battery.

in Europe and America, are the sledge or current-selector, and the commutator or current-reverser.

The sledge is a square piece of wood, which can be made to slide on the plate-carrier. This latter is marked with

figures progressing from the left to the right side, and indicating the number of cells to be used. The sledge should be so placed that it covers three of the wires visible on the plate-carrier: and the middle one of these then indicates the number of cells in the circuit. If we omit taking this precaution, there is collateral closure of circuit between two adjoining pairs, in consequence of which there is a copious development of gas, and the battery is more or less injured. At its lower surface, the sledge is furnished with two metal rails, which are long enough to touch the next pair of plates before the preceding one is left. This arrangement has the advantage of avoiding voltaic shocks on increasing or diminishing the power of the current, which is an important consideration, inasmuch as voltaic shocks, when given about the face and neck, give rise to giddiness and dazzling sensations of light, which are quite unnecessary and very disagreeable. In cases of hemiplegia, owing to recent cerebral hæmorrhage, they may even be dangerous.

The commutator is a roller of brass, divided in two parts by a central piece of ebony wood; the two parts are in contact with two springs which are connected with the rails of the sledge. The roller may be turned by means of a handle; and the studs for the insertion of the conducting wires, which are fixed at each side of the commutator, may thus be alternately placed in contact with the anterior and posterior surface of the rails. If the handle be placed perpendicularly, there is no metallic contact at all, and the circuit is therefore broken; when the handle is turned back, the stud on the right hand of the observer is in contact with the carbon, and is therefore positive; but, when the handle is turned to the front, the stud on the right side becomes negative. This may be easily verified by electrolysing water, when hydrogen will be seen to bubble up alternately at the

right and the left side, according to the position of the handle of the commutator.

In the lid of the box is a small compartment for electrodes and conducting wires; and it also contains a key and hook for undoing the plates if required.

Stöhrer's portable battery keeps in good condition for about three months, if it be daily used. It is rather less subject to polarisation than most of the other portable batteries. Occasionally, especially in hot weather, the

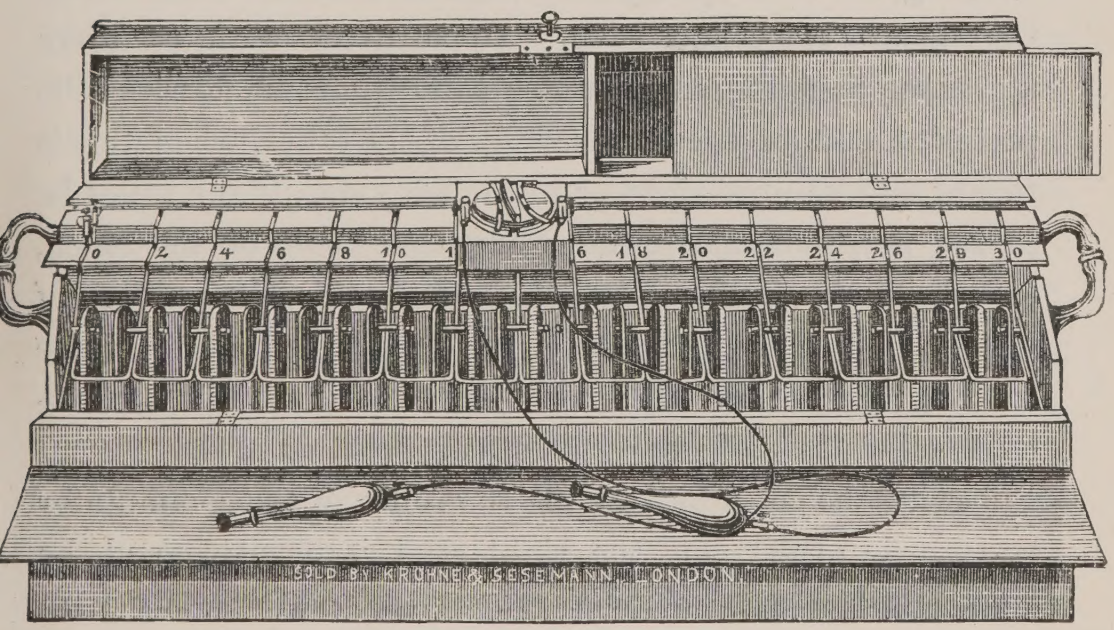

FIG. 53.—Stöhrer's Hospital Battery.

addition of a little fresh water to the liquid in the cells is to be recommended, so as to replace the water which has been lost by evaporation. If the current does not appear to be perceptibly refreshed by the addition of water, a new charge must be put in, and the sulphate of zinc, which is found adhering to the plates, must be removed. If the battery be well treated, it ought to last for twenty years.

b. The *hospital battery* (Fig. 53) consists of thirty or forty pairs of plates, contained in an oak case; the prices being

8*l.* 8*s.* and 10*l.* 10*s.* It is much larger and heavier than the one just described, from which it also differs in some other particulars. The cells are not of vulcanite, but of glass, and are placed on a tray, which is divided into two portions, each one of which carries fifteen or twenty glasses. The tray is raised much in the same manner as in the portable battery, and fixed by a turn of the black rod. There are a sledge and a commutator. This latter differs from the one in the portable battery. It consists of a wooden roller carrying two bent springs, the anterior ends of which touch the edges of two copper bows. Opposite to these latter there are three metallic studs, which come in contact with the posterior ends of the bent springs of the roller, when this is turned either to the right or to the left side. If the roller be placed perpendicularly, the springs and knobs do not touch, and the circuit is therefore broken. On the lower surface of the sledge there are two metallic rails, which fit into the groove of the plate-carrier. The two external studs of the commutator are connected with the anterior rail, and the central stud with the posterior rail. If the roller of the commutator be turned to the right, the right stud is negative, and the left positive; while, if it be turned to the left, the direction of the current is reversed.

c. The *electrolytic battery* differs from the hospital battery chiefly by the size of the plates and glasses, which is double that of the other; so that a corresponding larger surface is immersed, whereby the chemical effects are proportionately increased. The action is further intensified by the addition of a somewhat concentrated solution of chromic acid to the ordinary charge of the battery. This solution should have a claret colour, and two drachms of it are sufficient for each cell. The electrolytic battery contains twenty pairs of plates, and costs 6*l.*

Stöhrer's batteries will always command the respect of the

profession, not only because they were the first which fulfilled the important desideratum of portability, but also on account of their sound workmanship. We must, however, not shut our eyes to the fact that they, as other portable batteries, are liable to polarisation; and, secondly, that the carbon used in them is fragile. The battery, therefore, requires very tender treatment, more especially as the black rod, which is projecting outside at both ends of the battery, somewhat facilitates the reception of accidental injuries This is not merely theory, but we speak from actual experience. Stöhrer's instruments would be much improved by using a harder kind of carbon, by introducing leverage inside the box, and by the addition of a galvanometer. In London, Stöhrer's batteries may be procured from Messrs. Krohne and Sesemann, of Duke Street, Manchester Square, W.

Messrs. Mayer and Meltzer, of Great Portland Street, W., have had the ingenious idea of combining a constant battery of considerable power with an induction-apparatus in the same box (Fig. 54). Their instrument is, therefore, complete for all purposes of medical electricity. It has, however, yet to be shown whether there will be any real advantage to country practitioners in this arrangement, as it might be objected to it that, where the practitioner has two instruments, one for galvanisation and another for faradisation, and one of them were to get out of order, he would not be entirely deprived of some source of electricity while the one instrument was being repaired; while, if anything happened to the combined arrangement, he would be altogether bereaved for a time. We do not say this by way of disparagement of Mayer and Meltzer's idea, which deserves all praise, but merely to suggest that there are two sides to the question, and that it is well for the practitioner to weigh them both before deciding on purchase. These manufacturers, however, also construct galvanic and faradic machines apart.

The constant battery in this box is a modification of Bunsen's pair—viz. carbon and zinc, charged with diluted sulphuric acid (1 in 20). The carbon seems to be of a particularly good kind, as it is not nearly as fragile as Stöhrer's carbon, and generates a more powerful current than the latter. The battery is charged by lifting up the handles 1 and 2, and filling the cells rather less than half with the charge. They are then replaced, so that the fluid and the plates are not in contact. For putting the battery

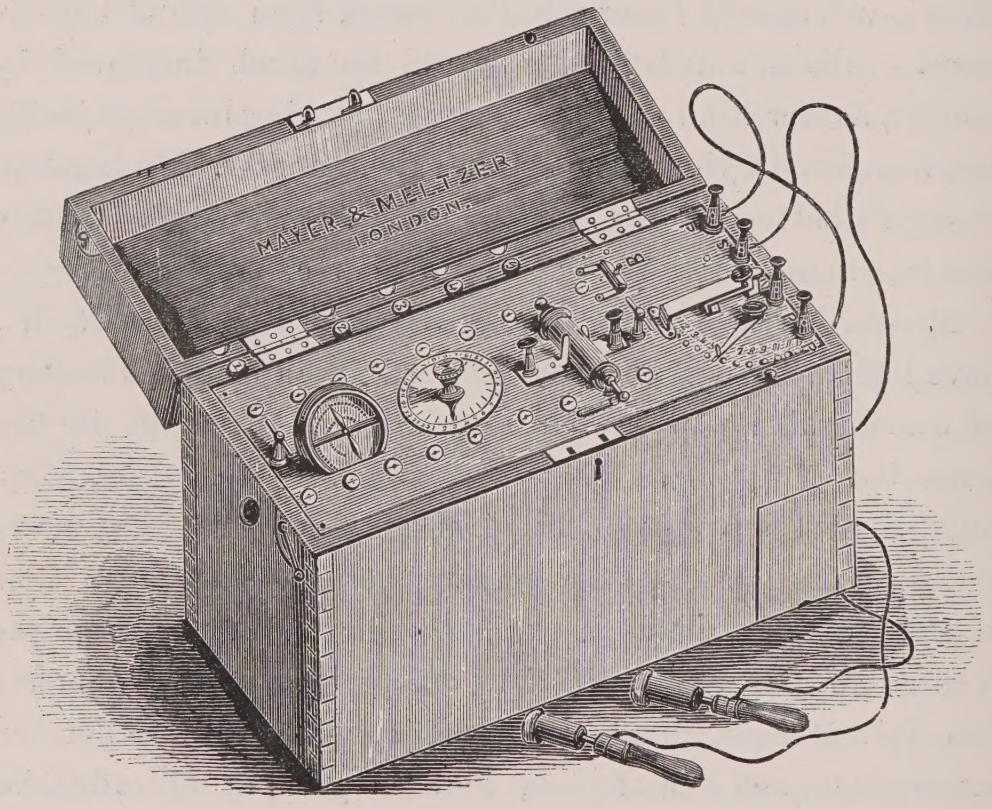

Fig. 54.—Mayer and Meltzer's Galvano-faradic Machine.

into action, there is a lifting arrangement, which raises the cells so as to make the liquid touch the plates, whereupon the galvanic current commences to flow. In the first specimens of this battery, the manufacturers had arranged the leverage on the outside of the case, so that every knob that was depressed raised a tier of four plates. In a later arrangement, however, nothing is projecting outside, which is a great improvement. The cells are raised by pulling up

metal rods inside the battery. There is a dial with an index for selecting the power that may be required ; and we have suggested to the manufacturer a slight change in its arrangement, so as to avoid the occurrence of voltaic shocks on increasing or diminishing the current. There is also a commutator or current-reverser on Stöhrer's principle, the central block in which is made of vulcanite. A galvanometer shows the condition of the battery. A valuable addition is an arrangement which allows to branch off for use any cells in the circuit, so that the chief strain is not, as in almost all other machines, put on the initial pairs of the battery. The chemical action is thus more divided, and the instrument can be used much longer than if the initial pairs always formed part of the circuit.

The induction-apparatus is put in action by turning the lever No. 5 so as to cover the two brass pins. This establishes the contact between the battery and the coil, and the familiar musical sound indicates that the faradic current is induced ; 6 and 7 are the studs for the primary, and 8 and 9 for the secondary current. The intensity of either current may be increased by passing an index along the semicircular row of pins marked from 1 to 12. The graduations are sufficiently extensive for allowing the use of a current which is hardly perceptible on the tongue and face, and all intermediate degrees up to a point which would not be relished by the most hardened garotter. The price of this instrument, which, in its latest development, is a perfect piece of workmanship, is 12*l.* 12*s.*

Leclanché's pair (p. 34), which was invented in 1868, was first utilised for medical practice by M. Gaiffe, of Paris.[1] He either employs the original Leclanché, or a modification of it, which has been introduced by M. Tripier, and which

[1] Gaiffe's batteries may be procured in London from his agents, Messrs. Lejeune & Perken, 24 Hatton Garden, E.C.

consists of the substitution of a piece of lead, surrounded with minium, for the carbon and manganese. These pairs are arranged in batteries varying from twenty-four to sixty cells. Fig. 55 shows one containing twenty-four cells. They are all furnished with a 'collector,' which allows the selection of any number of pairs in the battery, so that a gradual increase or decrease of power may be had without causing any interruption of the current. A galvanometer

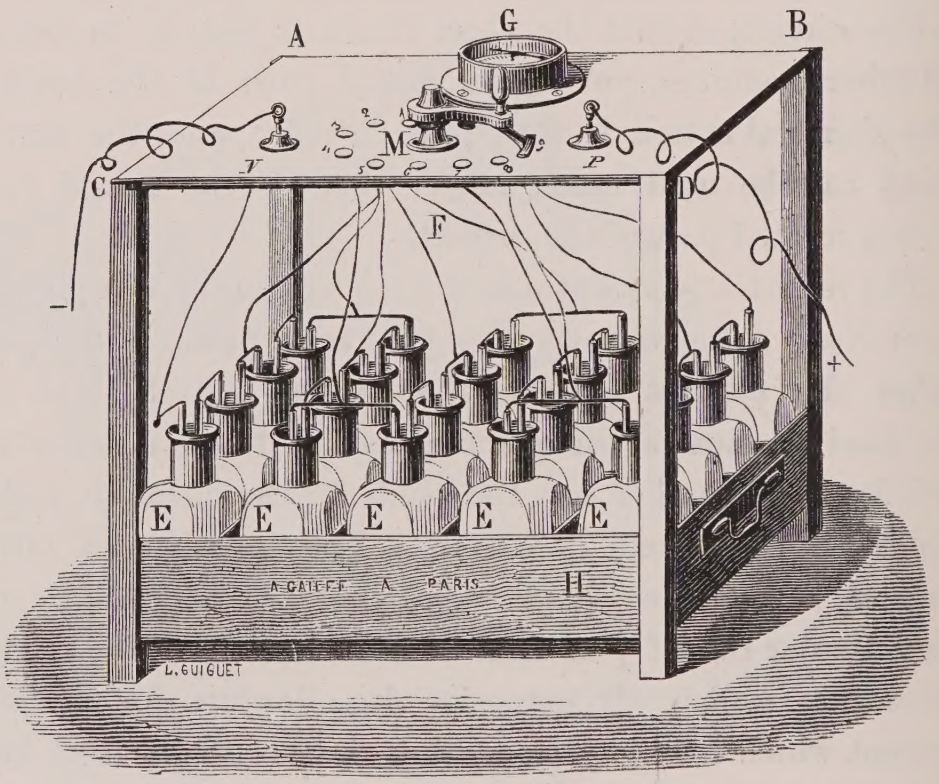

FIG. 55.—Gaiffe's Leclanché Battery.

is added to the instrument, showing approximatively the condition of the pair and the intensity of the current. Conducting wires and directors are enclosed in the case. A B C D is a tablet which carries the manipulating 'collector' M, the galvanometer (*g*), and the clamps (*P N*), in which the conducting wires are fixed. E E E E E are the pairs or elements of the battery, and F the conducting wires which connect the pairs with the collector. H is the box

containing the battery. M. Tripier has added to this battery a 'double collector' (Fig. 56), by the aid of which it is possible to put all the different cells successively into the circuit. This consists of a double row of metallic studs connected amongst each other by two and two, by means of conducting wires. The first twelve pairs are in communication with the positive poles of the battery P N; the thirteenth with the negative pole of the last pair of this battery. It is therefore possible, by attaching the conducting wires A P′ B N′ to the studs, to collect the current furnished either by the entire battery, or by any portion of it. The contact

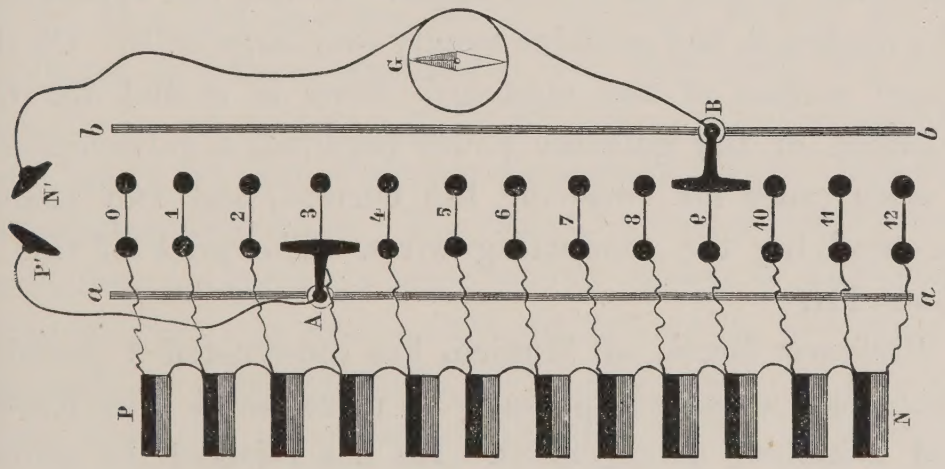

FIG. 56.—Tripier's Double Collector.

of the conducting wires with the studs is made by the springs P, A, and B. The spring A being in contact with any one of the studs of the right row, and the spring B with any one of the left row, either the commencement, or the middle, or the end of the battery can be utilised. The positive pole is under these circumstances that nearest to 0, and the negative that one which is furthest removed from it. In this way, where only a limited number of pairs is used, sometimes one, and sometimes another set may be used, so as not to throw the whole weight of the chemical action on the initial pairs of the battery. The integrity of

any part of the circuit may be shown by closing the circuit at N P′ by means of the galvanometer G.

The price of Gaiffe's Leclanché, of twenty-four pairs, is 4*l.* 10*s.*, every additional twelve pairs making an increase of 1*l.*; a sixty-pair battery costs therefore 7*l.* 10*s.* The addition of the 'double collector' raises the price from 12*s.* 6*d.* to 1*l.* 5*s.* A commutator may also be had, for reversing the direction of the current and producing voltaic shocks, at 12*s.* 6*d.*

Messrs. Keyser and Schmidt, of Berlin, have also constructed a Leclanché; but it is only fit for the consulting-room, and cannot be carried about. It has the appearance of a cupboard, and contains twenty-four large cells. On the upper surface of the cupboard there is a dial for the selection of the galvanic power required, a galvanometer, a contrivance for reversing the current, and two clamps for receiving the conducting wires. The price of this is about 11*l.*

Professor Beetz, of Munich, has constructed a portable Leclanché, which will probably be more useful than Keyser and Schmidt's arrangement. He has rejected the porous vase altogether, and fills the third part of an ordinary test-tube with a mixture of coarsely powdered carbon and pyrolusite; two-thirds of the tube are filled with a concentrated solution of chloride of ammonium. The inner surface of the upper part of the tube is coated with tallow, so as to avoid capillary attraction of the liquid and crystallisation. A cover of vulcanite closes the opening of the tube, admitting through its centre a rod of zinc, into which a brass wire is let in. The latter forms the zinc pole, while a platinum wire projecting from the bottom forms the carbon-pole. The tube is closed waterproof, but not air-tight. There can be no spilling of the liquid, but the gas which is formed during the galvanic action may escape from the

cover. Beetz has measured the electro-motive power of this battery, and finds it superior to the original Leclanché —viz. 1.4 Daniell's being 1. Twenty-four cells of Beetz-Leclanché are therefore equal to thirty-four Daniells, or thirty-six chloride of silver pairs. The price of the twenty-four cell apparatus is 6*l.*; and any number may be added to them at an expense of 4*s.* for each pair.[1] Leclanché's battery has also been utilised for induction machines; but of these arrangements we shall speak when we treat of faradisation.

Our own idea about Leclanché's battery is, that it is a most useful arrangement *where only short work is required of it.* It would therefore be an excellent battery for the physician or general practitioner who uses electricity occasionally in one patient; while for the electro-therapeutist, who has to get hard work out of a battery, Daniell-Muirhead is infinitely preferable. The reason for this is very simple—it is, that Leclanché is more readily subject to polarisation than Daniell. As soon as it is put into action, the water is decomposed and hydrogen developed. Now, it is quite true that the pyrolusite gives off a certain quantity of oxygen, which combines with the hydrogen to form water; yet hydrogen is always in excess, and thus polarisation is produced. *Polarisation is, in fact, inevitable in all batteries*, because, if a liquid were used that is incapable of decomposition, no galvanic action would take place; it is therefore the *degree* of polarisation which we have to consider in batteries. The polarisation current flows in a direction contrary to the battery-current, and has therefore the tendency to neutralise the original current. Where polarisation is energetic, this secondary current becomes so strong, after a time, that it completely neutralises the original

[1] This apparatus may be procured from Messrs. Th. Edelmann, of Munich.

current, so that the action of the battery is reduced to zero. Now this takes place in Leclanché's battery much more rapidly than in Daniell's, with the result that it will 'strike' after having been at work for some time. Of course, after the battery has been at rest, the current reappears, but only to disappear again after a certain amount of work. This is the principal reason why Leclanché has not superseded Daniell-Muirhead at the postal telegraphs, where it has been extensively tried; but, on the other hand, it has been found extremely useful for railway-signalling, where only a short action is required.

Another drawback to Leclanché's battery is the development of free ammonia, as soon as the water has taken up such an amount of that gas as to become saturated with it. This is chiefly remarked in the coarse batteries which have been constructed for telegraphic and railway purposes, and scarcely at all in Gaiffe's and Beetz's arrangements. Nevertheless it is a drawback.

A great advantage, on the other hand, is the wonderful enduring power of a good Leclanché. In this it surpasses any other battery that has yet been constructed; and its constancy, as far as this is concerned, appears to be practically unlimited.

It will thus be seen that Leclanché is the exact counterpart of Daniell-Muirhead, which will be presently described. In the latter arrangement, polarisation is to all intents and purposes reduced to zero, so that an unlimited supply of electricity can be got from it, even if one were to continue working with it day and night consecutively without any intermission. But, unless cleaned and nursed with a fresh solution of sulphate of copper every two or three months, it would soon cease to act altogether. In the telegraph offices, where a battery that works hard without ever 'striking'

even for a minute is indispensable, these batteries are cleaned almost every week or fortnight. In our own practice it is found necessary to have this done about once in every six weeks or two months. With Leclanché, on the other hand, no cleaning would be required for from five to ten years. For this reason practitioners residing in remote parts of the country, or in the colonies, where it is difficult to put a fresh charge into a battery, or to get it repaired, would find Leclanché invaluable; while it also recommends itself to others living more in the centres of civilisation as an instrument that will never refuse some amount of service, even after having been stowed away in the lumber-room for years.

M. Gaiffe has constructed two kinds of *chloride of silver batteries*, which differ according to the size of the pairs, and also in some other particulars. The smaller of these constitutes the most portable and least expensive constant battery which has as yet been constructed. It is made of 24, 36, 48, or 60 pairs of the battery, and may be carried in the coat pocket. A B C D (Fig. 57) is the box containing the battery,

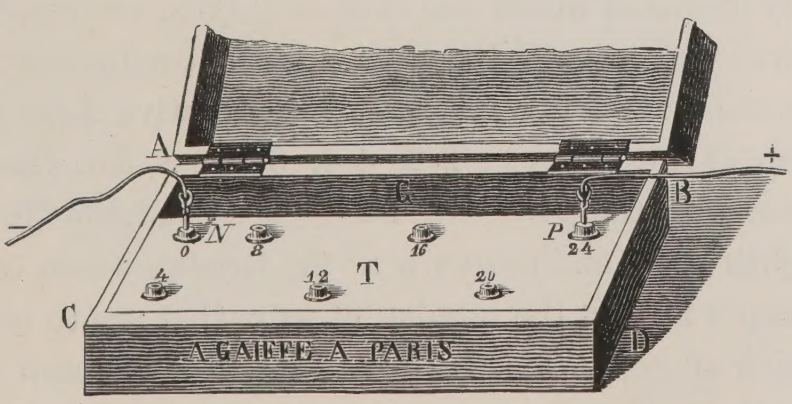

FIG. 57.—Gaiffe's small Chloride of Silver Battery.

and has the size of an octavo volume; T is the tablet, beneath which the several pairs are fixed; 0, 4, 8, 12, 16, 20, 24, are the studs communicating with the pairs, where

the conducting wires are inserted; P is the positive and N the negative pole; G is the case in which the conducting wires and the directors are placed. The price is about 35*s.* for twenty-four pairs, and rises by 12*s.* for every twelve pairs, so that one of sixty pairs costs about 3*l.* 10*s.* These batteries will work for eighty hours without being recharged. They are far superior to, and much cheaper than, Pulvermacher's chains. Experience shows, however, that a larger surface of metals is preferable, in a therapeutical point of view, to a small one; and we should, therefore, recommend these marvels of ingenuity and cheapness to those only who cannot afford to pay for the larger and more costly instruments.

The same manufacturer has constructed a larger chloride of silver battery (fig. 58), which not only lasts much longer than, but is also therapeutically preferable to, the one just described; although more bulky than the former, it is yet portable. It consists of from eighteen to sixty pairs, of which six are shown in the diagram (F F F F F F); N is the tablet covering the pairs; V V V V the binding screws; I the pedal by means of which the current may be interrupted; G the galvanometer; B B′ the clamps of the conducting wires; O O the stud communicating with the negative pole of the first pair of the battery; 2-2, 4-4, 6-6, 8-8, &c., the studs connected with the positive poles of the second, fourth, sixth, and eighth pairs, and so on; N M′ the handles which connect the clamp B B′ with the number of pairs that are to be used, and which allow the practitioner to act with different sets of pairs in the battery, so as to divide the chemical action; E E′ are the directors. This apparatus is much more costly than the one previously described. An 18-pair one costs 8*l.*, and the price rises by 2*l.* for every additional six pairs, so that the 60-pair one is 22*l.* A commutator may be added to any of these instruments at the expense of 12*s.* 6*d.*

These machines will work nearly eight hundred hours without being recharged, and do not require any further attention in the intervals except putting the current on zero. If this be done, there is no chemical action, and consequently no destruction of the metals.

Stöhrer has likewise constructed a chloride of silver

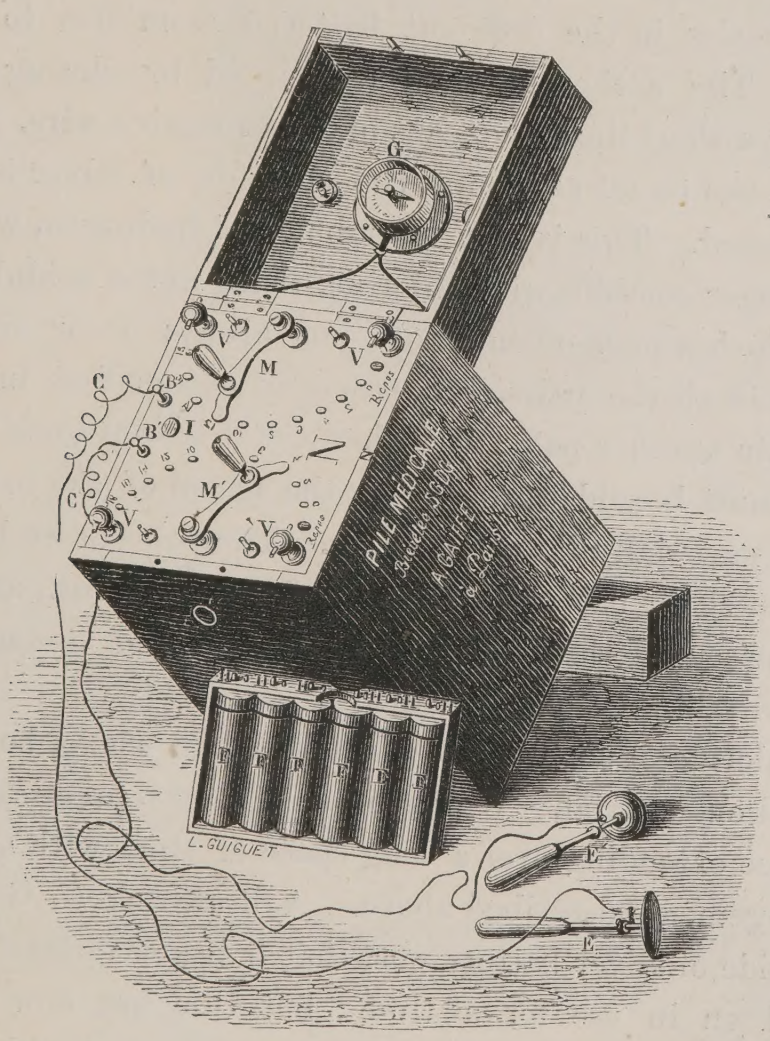

FIG. 58.—Gaiffe's Large Chloride of Silver Battery.

battery, which consists of forty, fifty, or sixty pairs. A small quantity of chloride of silver is placed on the bottom of a cylindrical glass-tube about six inches high, and a strip of silver is made to touch the chloride of silver when the glass is raised. A cross of zinc is inserted in the upper portion of the tube, at a distance of about three inches from the chloride of

silver. The battery is charged with diluted sulphuric acid, in the proportion of one to ten, and by a lifting arrangement the pair may be brought into contact with the fluid, or withdrawn from it.

Some chloride of silver must have been decomposed before the battery commences to act. The time which is necessary for this varies in the different batteries from five to ten minutes. The action may be accelerated by closing the circuit for a short time by means of a conjunctive wire. The battery ceases to act as soon as the chloride of silver is entirely reduced. This is seen by bubbles of hydrogen, which can no longer combine with chlorine, rising in the acidulated water. Such a phenomenon does not always occur simultaneously in all the pairs, but generally occurs first in one and then in another pair; but wherever it is seen some fresh chloride must be added at once, or the action of the battery would be materially interfered with. The price of Stöhrer's chloride of silver battery is from 6*l*. 6*s*. to 10*l*. 10*s*., and it may be procured through Messrs. Krohne and Sesemann, of Duke Street, Manchester Square.

The chloride of silver battery may, on the whole, be said to be still on its trial. We have no intimate practical acquaintance extending over a long space of time with any of the arrangements described above. A drawback to Gaiffe's old chloride of silver battery was, that it began to leak after having been in use for a time; but this has now been obviated by employing a smaller quantity of liquid than formerly.

A portable battery, which for its good qualities has during the last three or four years received a considerable share of popularity, is Foveaux's modification of Smee's (fig. 59). The adjoined diagram shows a battery consisting of fifty pairs of plates, and such a strength is sufficient for almost all cases which present themselves in practice. Messrs.

Weiss, however, likewise construct batteries containing a lesser number of pairs—viz. twenty or thirty—which are

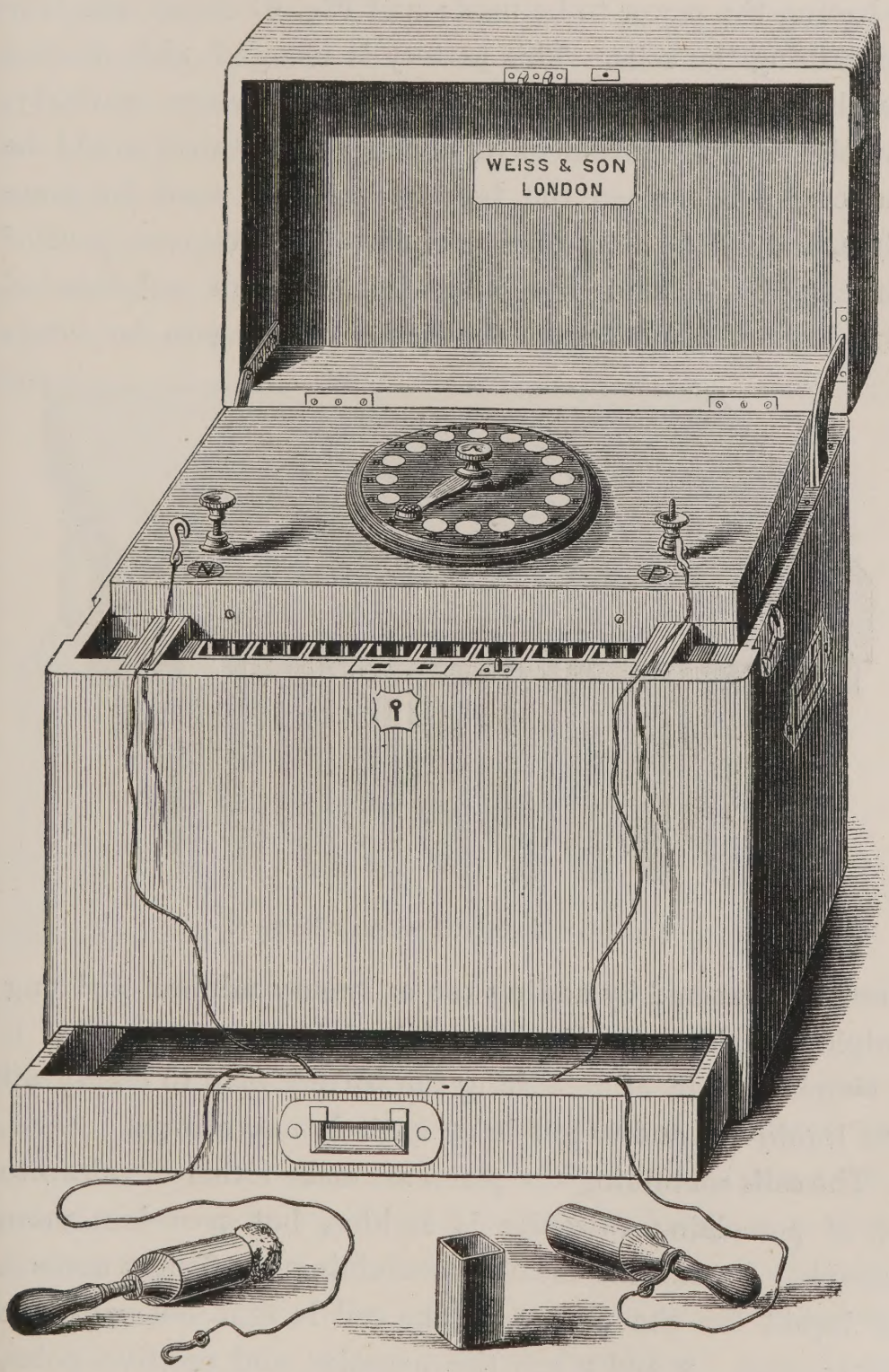

Fig. 59.—Foveaux's Constant Battery.

strong enough for cases where the constant current is used

about the neck and face. Fig. 60 shows the plates of platinised silver and zinc, attached to a board and dial, for selecting the power to be used; and Fig. 61 shows the tray containing the cells. This battery is charged with diluted sulphuric acid, in the proportion of one to twenty or thirty. At the commencement of its action, one to thirty would be sufficient; but when the battery has been used for some time, and by the electrolytic effects of the current part of the sulphuric acid has been lost through sulphate of zinc having been formed, the action may again be consi-

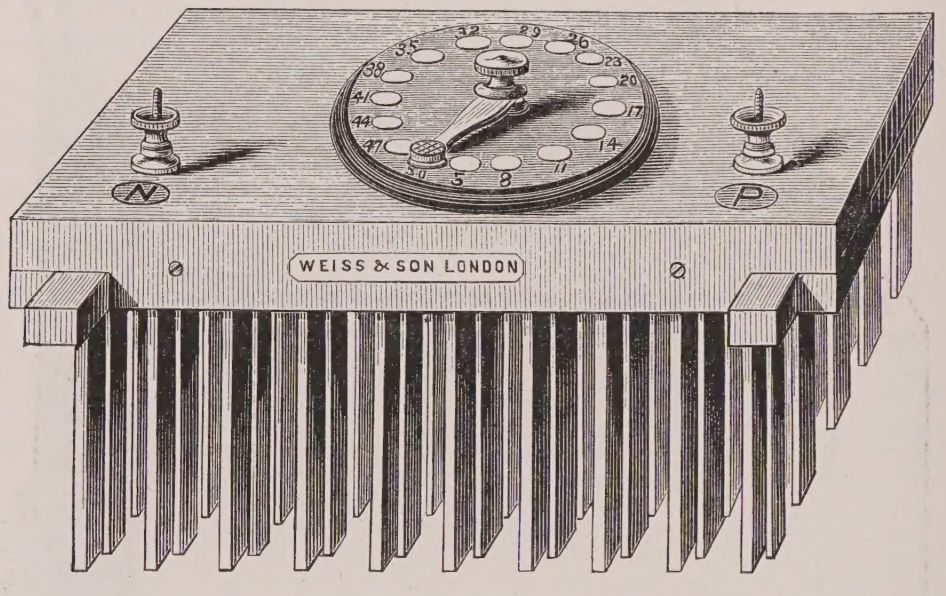

FIG. 60.—Plates of Foveaux's Battery.

derably increased by adding ten or twenty minims of strong sulphuric acid to the liquid contained in each cell. This is a simpler mode of refreshing the battery than to empty all the liquid out and to put in an entirely new charge.

The cells containing the plates are made either of vulcanite or of porcelain; vulcanite is lighter, but porcelain more durable. A vulcanite measure containing a sufficient amount of liquid for the charge of one cell is sent out with the instrument. N and P are the negative and positive poles, and the power of the current is regulated by turning the index on the dial. The figures opposite to each stud in the dial indicate the number of pairs brought into action.

When the battery has once been charged, simple closing of the lid puts it out of action, while opening the lid renews the galvanic effect. This is done by keeping the plates suspended in the case, while the tray containing the cells is lifted up and down by a lever arrangement. In order to prevent any unnecessary destruction of metals, it is therefore enough to close the battery and put it away.

Foveaux's battery furnishes a reliable current, but is, of course, subject to polarisation, and therefore diminishes in activity when it has been used for some time. When the battery is not freshly charged, the current sometimes sensibly

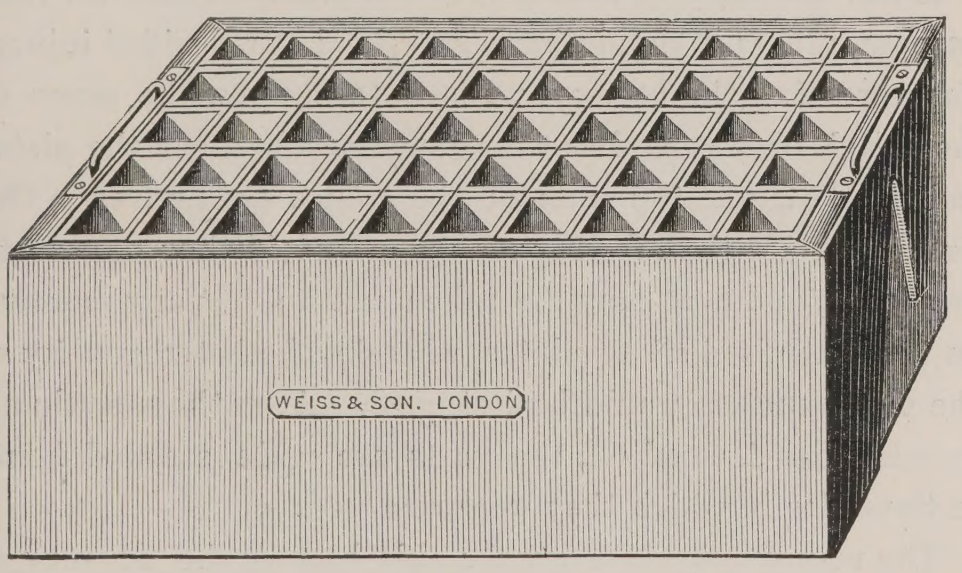

FIG. 61.—Tray of Foveaux's Battery.

diminishes in intensity during a single application of electricity. In order to obviate the inconvenience attaching to this, we recommend those who are in the habit of using this instrument to close the lid and then immediately to reopen it, when the current will be found to have returned to its previous power. The reason for this is a simply mechanical one: by taking the plates out of the liquid and then immersing them again, the bubbles of hydrogen which polarise the platinum are wiped off, and polarisation is thus done away with for the time being. If such opening and

closing of the lid do no longer answer for rendering the strength of the current more uniform, a fresh charge is required. Another circumstance showing that the battery is weak is that the metallic ends of the conducting wires, on being held together, do no longer cause the peculiar hissing noise, owing to a copious development of hydrogen, which is produced when they are connected in a fresh condition of the battery. If a perceptible hissing sound be produced in the battery without the circuit being closed by a conjunctive arch, the zinc requires re-amalgamation.

Foveaux's battery can be refreshed by its possessor, so that it is not necessary to return it to the manufacturer for that purpose, unless it should have sustained any decided injury. For refreshing the battery, we have to unscrew the cover of the plateboard, as well as the connexions between the plates and the dial, and the nuts of the plates themselves. The zinc plates are then freshly amalgamated if they appear to require it, and care must be taken not to put any mercury on the platinised silver-plates, whereby the heterogeneity of the electromotors would be destroyed. After the superfluous mercury has drained off, the parts are again screwed home in the order in which they were removed.

The manufacturers claim for this battery the advantages of simplicity, portability and durability, to which we may add that of solidity of construction. Foveaux's battery will stand a good deal of knocking about without getting hurt by it. We have taken it repeatedly to the country, and not given any over-anxious attention to it during its passage between our house and the patient's residence (in one instance over 500 miles with sea-transit). On no occasion has the battery left us in the lurch, but was on arrival always found in working condition. This is an important consideration, as some batteries are very fragile, and keep their proprietors in a state of nervous excitement and apprehension, whenever

they are removed from the familiar cupboard. Fifty pairs of this battery cost 12*l*. 12*s*.

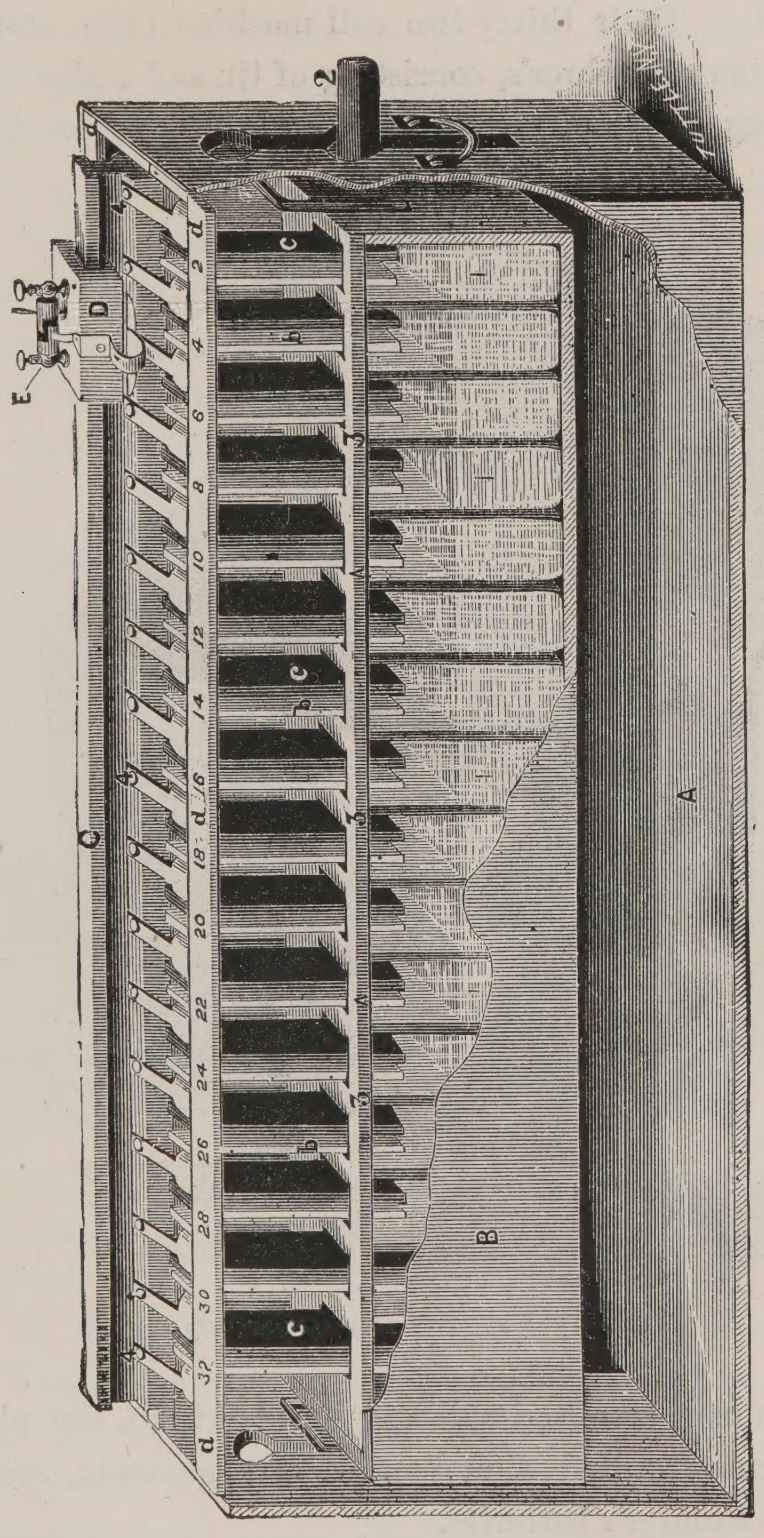

FIG. 62.—Constant Battery of the New York Galvano-Faradic Company.

Our American cousins have of late years been forward to emulate European manufacturers in the production of con-

stant batteries. Those constructed by the Galvano-Faradic Manufacturing Company of New York seem to be very well made. Their thirty-two cell machine (Fig. 62) is a modification of Stöhrer's, consisting of tin and carbon plates, and having an arrangement by which the cells containing

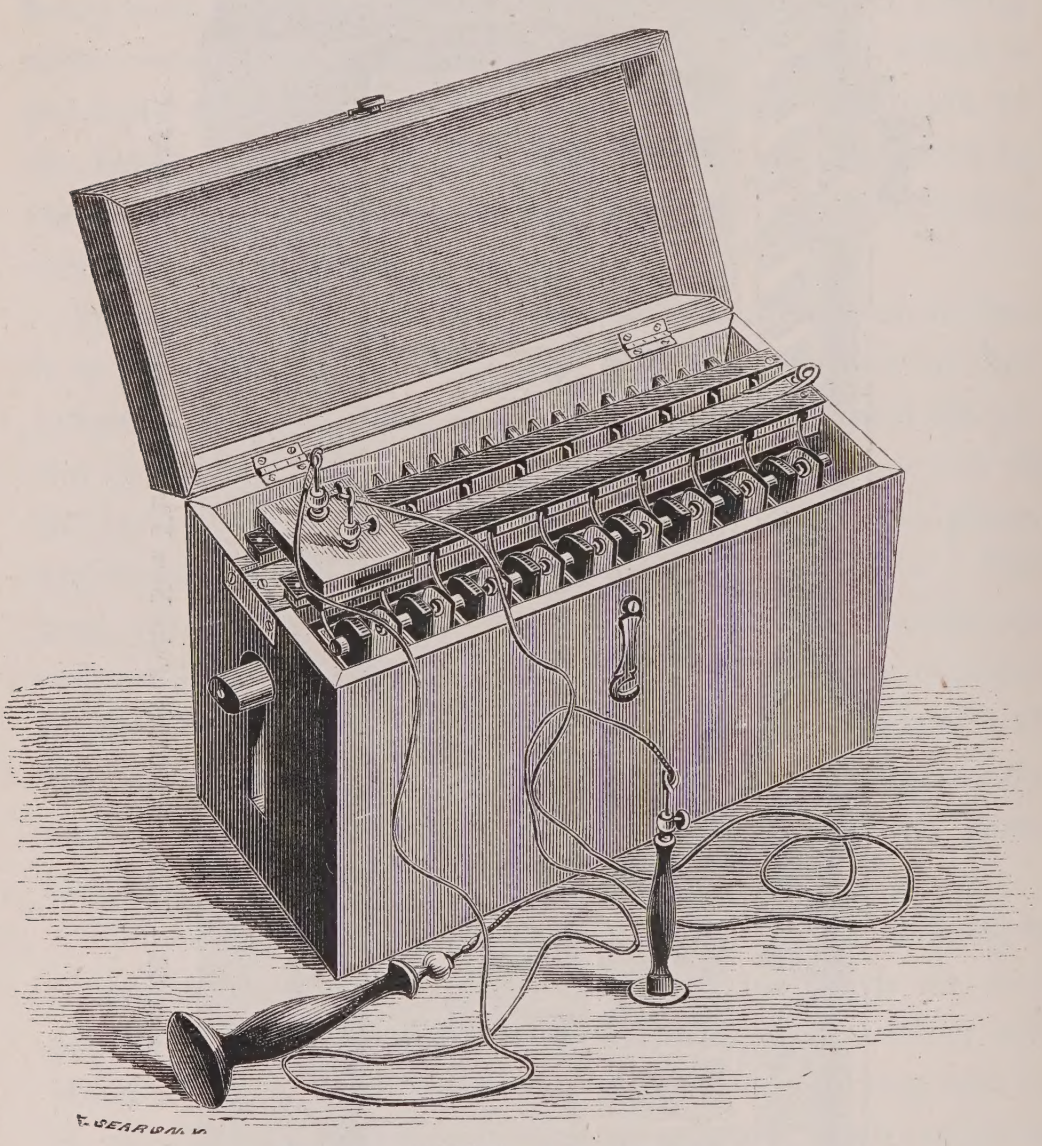

FIG. 63.—Kidder's thirty-cell Battery.

the charge may be raised up to, or lowered from, the plates. The commutator, sledge, and other arrangements, are the same as in Stöhrer's batteries.

Dr. Jerome Kidder's batteries (Figs. 63, 64, and 65) are, according to Dr. Beard, of New York, who has used them ex-

tensively, very convenient for practice. They consist of carbon and zinc plates, with the usual charge. Dr. Kidder uses, instead of Stöhrer's sledge, what he calls a 'circular current-selector' for increasing and diminishing the current without interrupting it. It is much of the same construction as Foveaux's and Mayer and Meltzer's dial. It consists of a circle with a vulcanite base, which carries small brass plates connected with the different cells of the battery, and separated from each other by pieces of ivory. The circle carries two arms resting on wheels, and revolving on a pivot in the centre. One of these is short, and the other long;

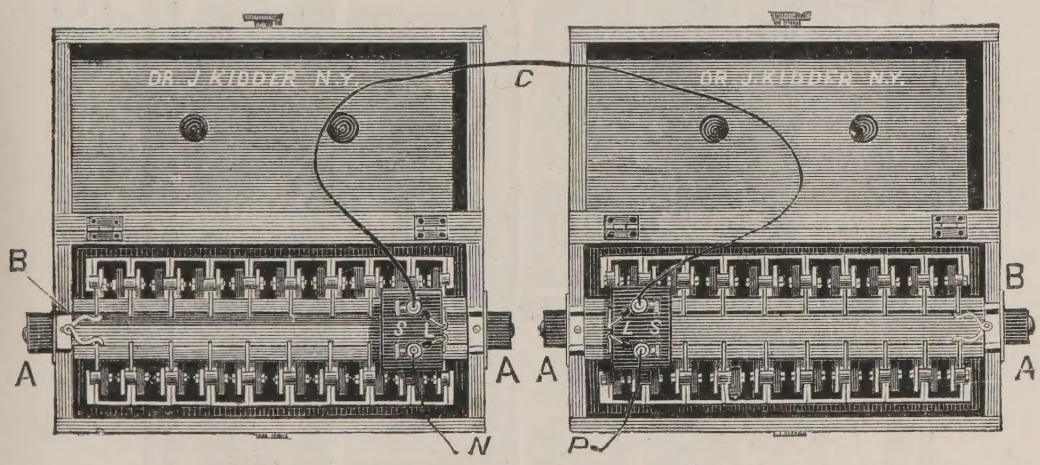

FIG. 64. FIG. 65.

Kidder's Small Batteries.

and, according as the long or the short arm is moved, the current is increased or diminished, without or with interrupting it. A commutator and a toothed wheel for the interruption of the current are added to the battery.

Fig. 63 shows a thirty-cell battery, which appears to be amply strong for the ordinary requirements of the practitioner. Dr. Kidder, however, likewise constructs twelve- and twenty-cell batteries, which are sufficient where the continuous current is used about the head, face, and neck. (Figs. 64 and 65.)

Frommhold's apparatus (Fig. 66), consists of thirty-two

pairs of zinc and platinised lead, which latter is substituted for silver. It is furnished with a dial and galvanometer. By means of a peculiar arrangement it is possible to immerse

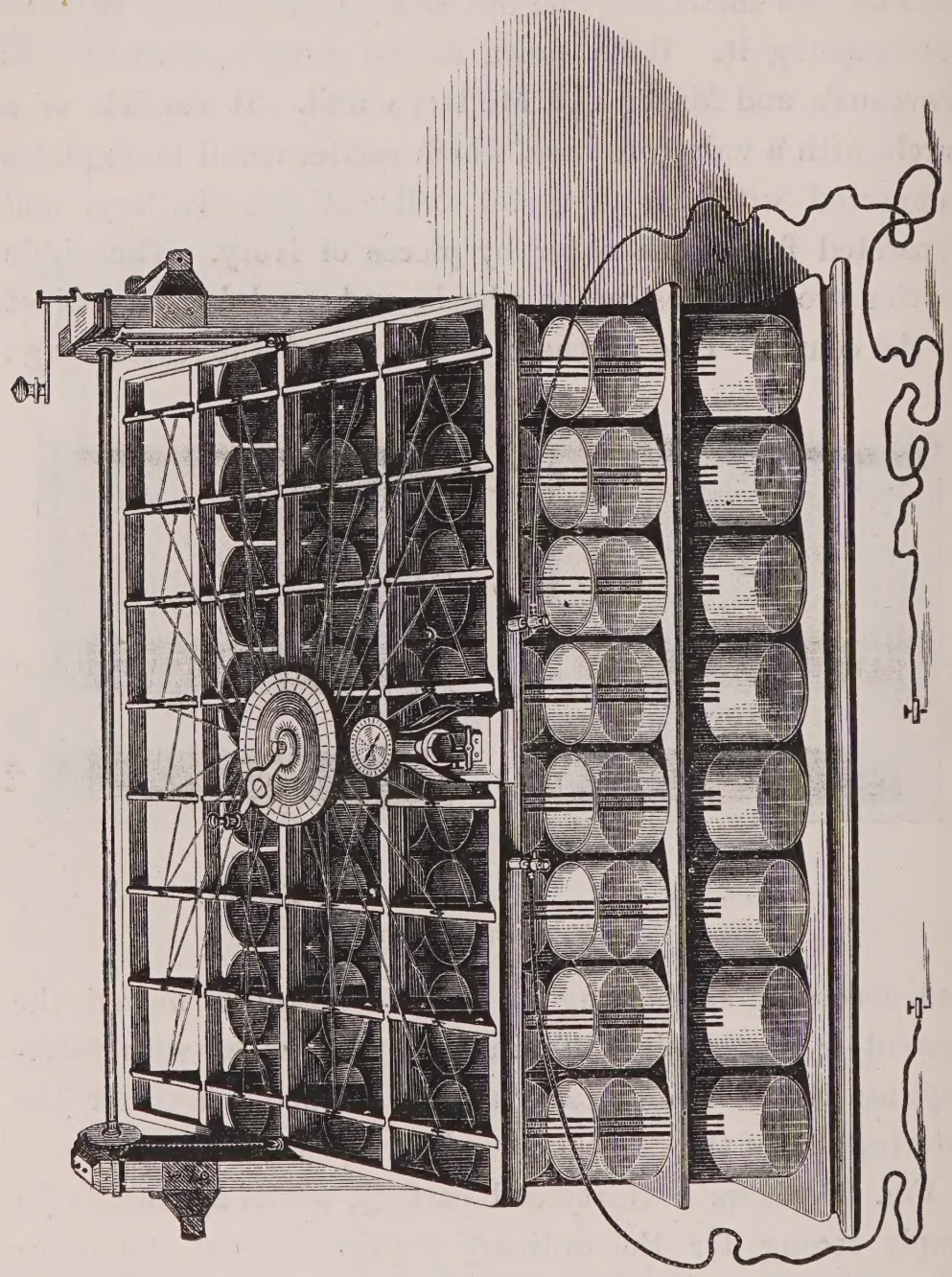

Fig. 66.—Frommhold's Lead and Zinc Battery.

the plates more or less deeply into the exciting liquid, so that not only intensity, but quantity likewise, may be changed during the application.

Thomsen's apparatus has the peculiarity of containing only one galvanic pair, but which is made to furnish a sufficient amount of electricity, by utilising the principle of polarisation. The pair used is either zinc and carbon, or zinc and platinum, charged with nitric or chromic acid, and must readily decompose water. The battery itself consists of two open boxes, each of which is, by means of twenty-six platinum plates, divided into twenty-five cells, so that one side of each plate belongs to one cell, and the other to the next cell. Now it is well known that if two platinum plates, immersed into diluted sulphuric acid, are touched by the poles of a galvanic battery, and the latter is removed while the two plates are connected by means of a wire, an electric current is generated which travels in a direction opposite to that of the battery. The plates are, in fact, polarised by the deposit of hydrogen on one and of oxygen on the other. Both these gases being in the nascent state, they quickly combine again to form water, and the electric current produced by their appearance has therefore a short duration ; on the other hand, it is easy in a short time to charge by polarisation a large number of plates, so that, if the latter are combined to form a battery, a current of high tension may be obtained, the duration of which is prolonged by means of the following contrivance :—A flat ring, made of an insulating material, contains as many pieces of metal as there are plates in the battery, each piece being connected with the corresponding plate by means of a fine silver or copper wire. The ring is traversed by a horizontal axis, furnished at the top with two branches insulated from one another, and connected with two clamps for receiving the conducting wires of the galvanic battery. The two branches represent the poles of the pair, and carry a spring, so arranged that if one of them touches the metal pieces of the ring, the other spring

touches the next. This axis may be turned round by means of a weight, or clockwork, or a hammer, such as is used in induction machines; and in this manner each plate is successively charged with hydrogen on one side and oxygen on the other. One turn of the axis therefore charges the whole battery, which is thus always ready to act. The intensity of the current is regulated by the more or less intense action of the galvanic pair, and this is regulated by

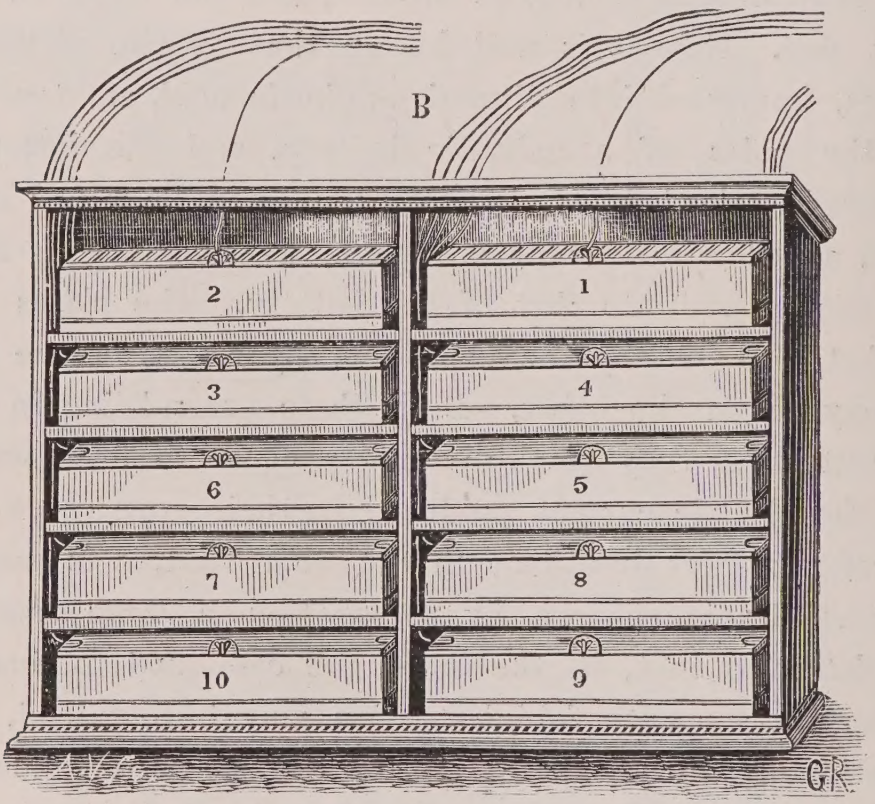

FIG. 67.—Becker-Muirhead's Battery.

interpolating a metallic wire of different lengths into the circuit, so as to increase or diminish the resistance of the pair *ad libitum*. The apparatus is expensive, but does not require any subsequent outlay, and, being portable, may in time come to be extensively used for out-door practice.

All the portable batteries which we have hitherto described are, however, much inferior in therapeutical virtues to that modification of Daniell's battery, which is in England known

as *Becker-Muirhead*, and in Germany as Siemens-Meidinger. Scientifically speaking, this is the only really constant battery in existence, as polarisation has been reduced in it to an imperceptible minimum. Polarisation is avoided by using no acid, but ordinary water for the zinc, and a solution of cupric sulphate for the copper. The chemical changes therefore which must always go on in the battery are infinitely retarded, and no perceptible diminution of the intensity of the current occurs for weeks and months, even if the instrument be freely used.

This battery (Fig. 67), which we have had in use for the last ten years, has been put up for us by Mr. Becker, of the firm of Elliott brothers. It consists of ten teak boxes superposed upon each other in two rows, as shown in the diagram, and furnished with wires so as to enable us to collect the current of every five cells. The wires are carried from the basement of the house to the ground floor, and joined to a pole-board fixed on one of the walls of the consulting-room. B W (fig. 68, p. 318) are the battery wires which are insulated except at their extremities, which are soldered to a silver plate hidden in the dials D D′. The dial on the left-hand side will give the current of from 5 to 45, and that on the right, the current of from 50 to 100 cells. C W are the conducting wires connected with the pole-studs, N P, and furnished at their other ends with the directors D; B′ W is the wire connecting the circuit of the battery with a tangent galvanometer G, which indicates the strength of the battery current. Under ordinary circumstances, the current does not pass through the galvanometer, but it may be made to do so by connecting N and P by means of a conducting wire, and unscrewing the knob K, whereupon the deflection of the needle gives us an indication of the condition of the battery which is out of sight. The ordinary galvanometer is really not much more than a galvanoscope, while the tangent

galvanometer gives us an accurate measurement of the current.

We have already seen that in the Becker-Muirhead battery, polarisation is to all intents and purposes reduced to zero ; but it has other important advantages. It is very easy to nurse and never gets out of order. We have used it almost daily for the last ten years, and have never on any

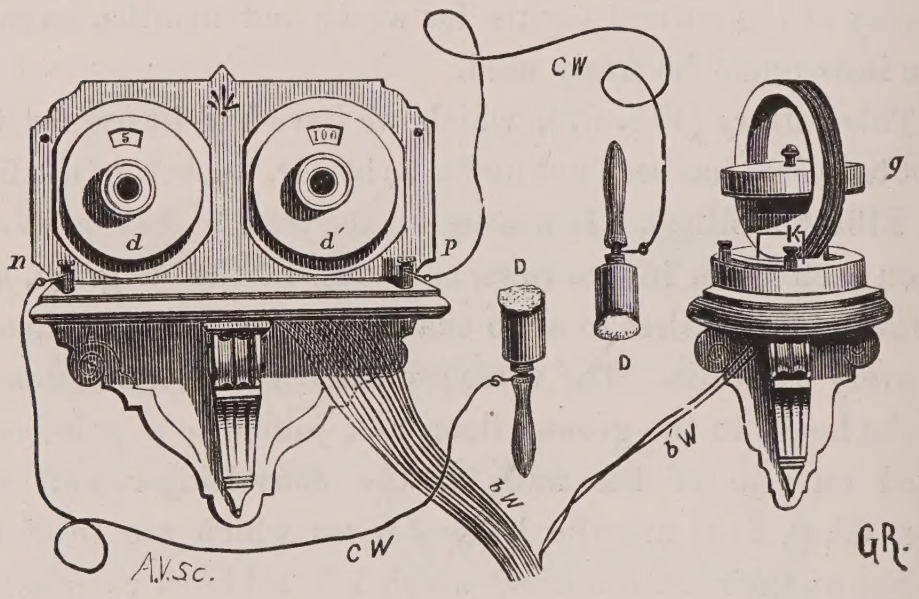

FIG. 68.—Pole-board of Becker-Muirhead's Battery, as used by the Author.

occasion been disappointed with its effects. On the whole, it is best to have the apparatus refreshed once a month, and this can be easily done by an intelligent mechanic in less than an hour. The plates and porous vases must be renewed once in every three or four years, but all the other parts of the instrument remain permanently useful.

It is however not only the constancy, the ease with which the apparatus is nursed, and its conservative qualities generally, which must recommend the use of this instrument, but there are several other considerations which are somewhat more difficult to explain, and which yet go far towards establishing its absolute superiority over other smaller

machines. *The current produced by the portable batteries is more painful than that produced by the large stationary battery.* Now it is very important, in the treatment of most nervous disorders, to avoid giving pain. If much pain be produced by the application, it is often necessary to change the places where the electrodes are applied. Moreover involuntary muscular contractions will occur in consequence, and the really constant flow of the current through the organs is thus impeded. This is one of the reasons why the therapeutical results obtained with the large battery are better than those obtained with the smaller instruments, more especially in affections of the nervous centres, and in the different forms of neuralgia. The characteristic feature of Becker's battery is the large surface of the metals composing it, and the absence of acids. Now the power of decomposing water, and the magnetic properties of the two currents produced by a large and a small battery, may be the same, and yet there is a difference in their physiological and therapeutical effects. *The same electro-motive force which in a portable battery is crammed into a square inch has perhaps the space of* 10 *or* 20 *square inches to spread over in the large battery.* Again, in a short time after being put in action, the metals of the portable battery become irregular in their production of electricity, and local currents are formed which interfere with the flow of the principal current. These circumstances serve to account, at least to some extent, for the superiority of the large over the portable batteries. It is, however, more the province of the physicist than that of the physician to analyse the minutiæ of these matters. As practitioners, we have simply to register the fact that the large stationary Becker-Muirhead is better than all the portable batteries which have been constructed. It should therefore be *the* hospital battery, and is indispensable to all those who occupy themselves more particularly with

the study of the influence of electricity upon neurotic conditions.

Other instruments.—The most essential instruments besides the battery are the conducting wires on rheophores, and the electrodes or directors, by means of which the current is conveyed to the body.

Conducting wires should be made of flexible copper thread, two or three yards long, and carefully insulated with silk or cotton, or some similar material. I always employ differently coloured conducting wires for the two poles, in order to be able to tell at once the direction of the current, viz. such insulated by green or black silk for the negative, and such insulated by red or yellow silk for the positive pole. This saves a great deal of trouble in case of the wires becoming entangled. Flexible india-rubber, which is frequently used, and protects the wires better from without, is nevertheless one of the worst substances for insulation, as it contains a small amount of sulphuric acid, which rapidly corrodes the metal, even if the wire be first covered with silk or cotton. I have therefore long ago given up the use of india-rubber insulation, as being most deceptive and leading to great disappointment. I am surprised that Ziemssen, in the last edition of his work, should speak favourably of this material. It must also be borne in mind that conducting wires, however well they may have been insulated in the first instance, suffer a good deal from wear and tear, and should, therefore, from time to time be replaced by fresh ones.

The electrodes most commonly used are metallic cups with a diameter of from half an inch to three inches, fixed on insulating handles of wood, and furnished with a screw or clamp, for the attachment of the conducting wires. These cups are filled with sponge moistened with warm water or salt water. The sponge should project completely

beyond the metal, so that during the application the metal does not touch the skin. I have in some cases found it useful to have two sponge-cups branched off from one stem,

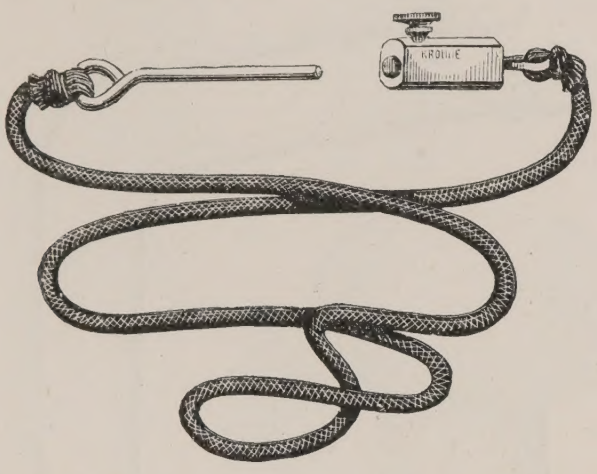

FIG. 69.—Conducting Wire, with Rod and Clamp.

so that two separate points may receive the influence of one pole at the same time. (Fig. 73, p. 323.)

Messrs. Weiss have lately constructed for me some very convenient sponge-electrodes, the cups and stems of which are made of vulcanite, and the inside of which is furnished with a thick wire covered with platinum. These electrodes have the great advantage of being always scrupulously clean, which is not the case where brass and wood are employed.

There is, as a rule, little difficulty in keeping the cathode of an ordinary pair of electrodes in good order, since hydrogen and alkalies, which are evolved at the negative pole during the transmission of the current to the human body, have no corroding action upon metals. It is, however, different with the anode, which is rapidly oxidised and chlorinated, and therefore soon becomes a bad conductor. This condition of the anode is a frequent cause of a battery not yielding a proper current, and should be looked to before the commencement of the application. The sponges which are used likewise require to be frequently renewed, especially when they assume a greenish-blue colour, showing that they have

become impregnated with a solution of copper. As platinum is not attacked in the way in which brass or

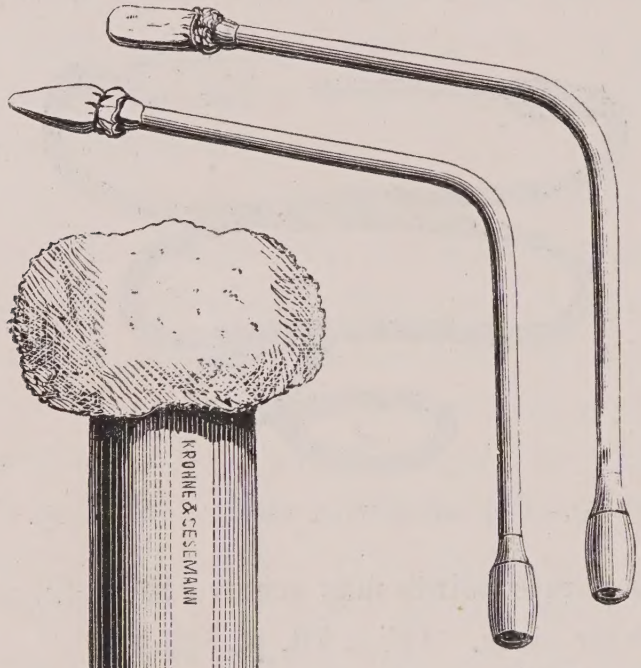

FIG. 71.

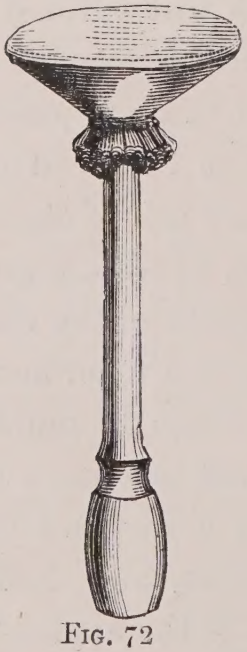

FIG. 72

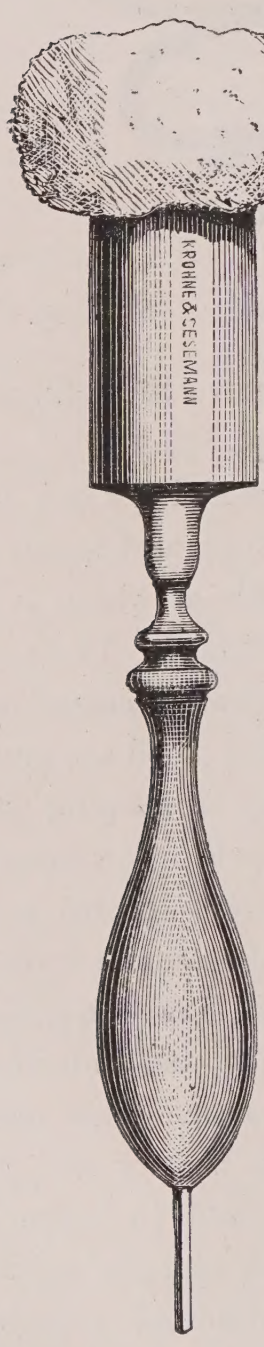

FIG. 70.

copper are, Weiss's electrodes are much preferable to the old-fashioned ones.

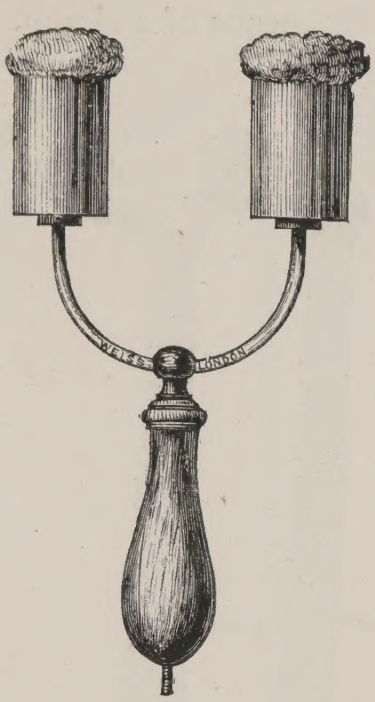

FIG. 73. Author's Double Electrode.

It is useful to have a considerable variety of electrodes, in order to suit the various cases as they present themselves. Stöhrer's charcoal electrodes are chiefly appropriate when a weak battery is employed; but they must, previous to the application, be covered with fine sponge or chamois leather, for if they are directed to the skin without such covering, they severely blister it, in the same way as metals.

Unpolarisable electrodes.—We have seen that by applying metallic electrodes to the skin, cauterisation, with its consequences, is produced, more especially at the negative pole. This may be avoided by not allowing the accumulation of the alkalies which are set free at the cathode, but forcing them back into the electrode. Hitzig,[1] acting upon the suggestion of Regnauld and Du Bois-Reymond (p. 44), has constructed unpolarisable electrodes suitable for medical practice. This unpolarisable electrode consists of a hollow

[1] Berlin Klinische Wochenschrift, 1867, No. 39.

amalgamated cylinder of zinc, let into a similar piece of vulcanite, and connected at its lower end with the conducting wire of the battery by means of a clamp. The zinc cylinder

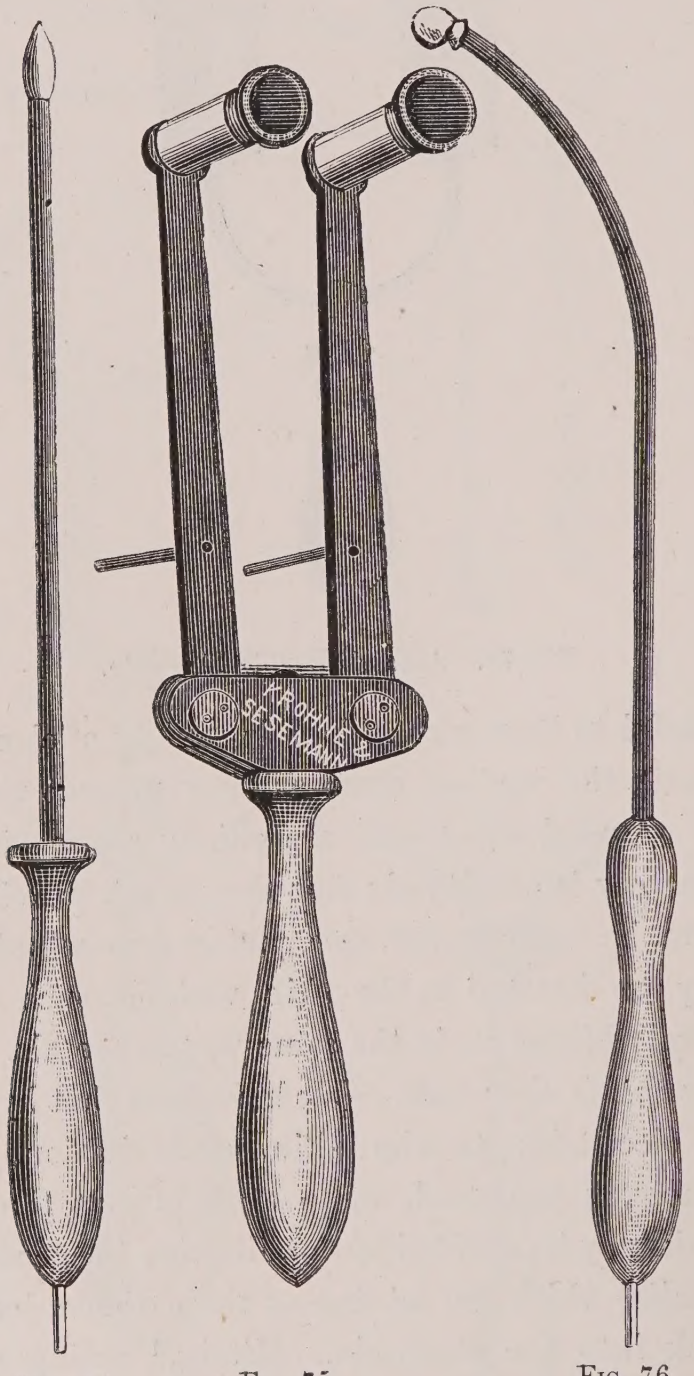

Fig. 74. Fig. 75. Fig. 76

is open above, and may receive a saturated solution of sulphate of zinc. A stopper of clay, which is mixed with a solution of sulphate of zinc, closes the cylinder; and both

above and beneath the stopper there is a piece of lint fixed to the vulcanite. A second piece of vulcanite is superposed

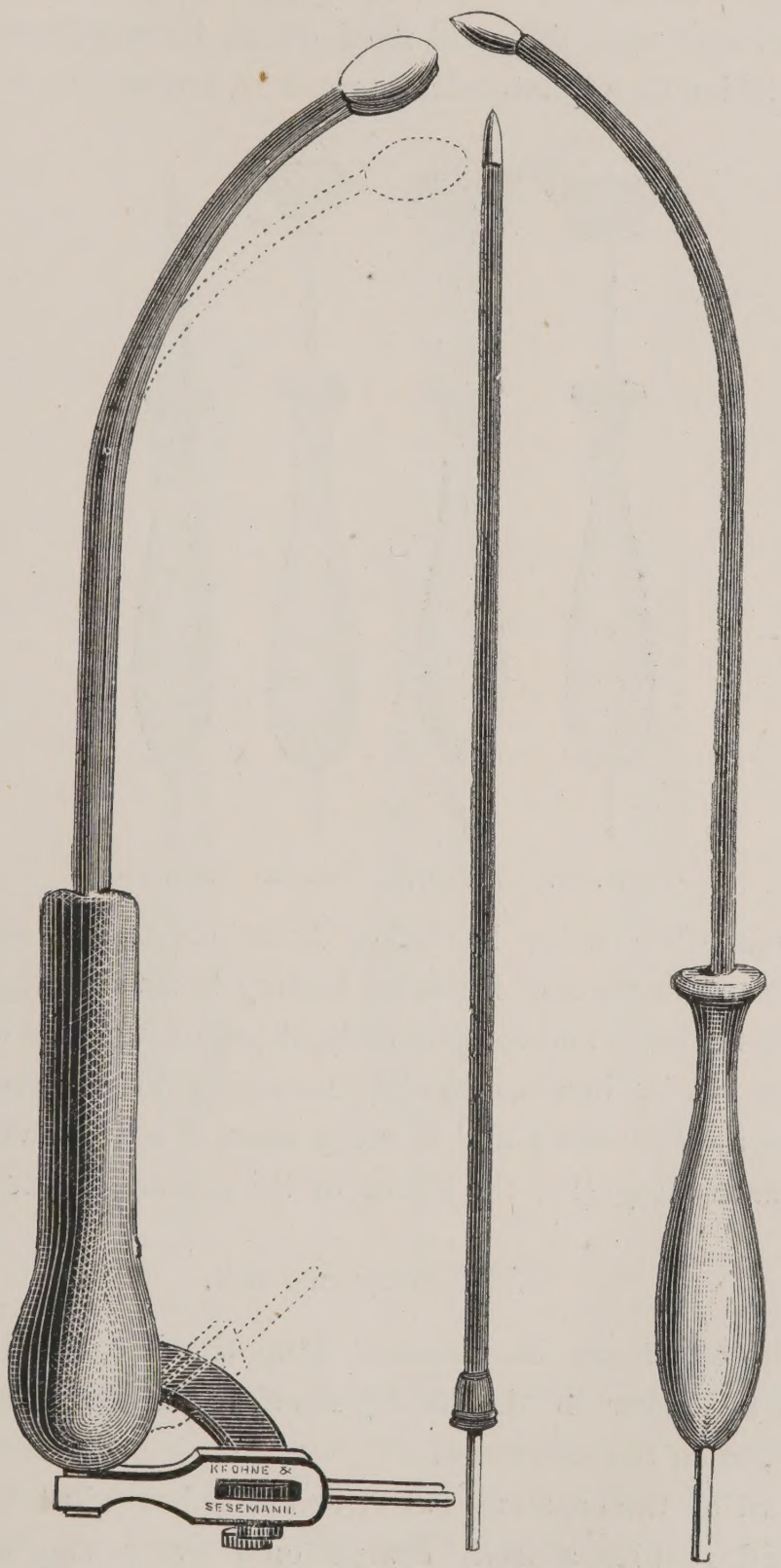

FIG. 77. FIG. 78. FIG. 79.

on this, and filled, in its upper funnel-shaped portion, with Swedish filtering-paper, moistened with a weak solution of chloride of sodium (1 or 2 in 100 parts of water). This is also covered with lint, and fixed on an india-rubber ring. The solution of sulphate of zinc must be renewed from time

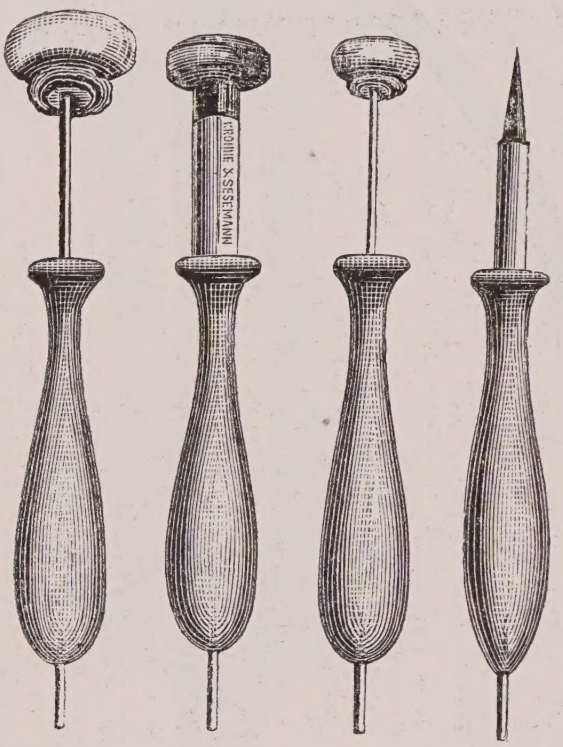

FIG. 80. FIG. 81. FIG. 82. FIG. 83.

to time. We may, by using these electrodes, cause a current of 50 pairs of Daniell's battery to act on the skin for twenty minutes and longer, without producing any cauterisation. It is, however, rarely necessary to use such prolonged applications; and in many cases it is not advisable to eliminate altogether the action of the current on the skin.

The Battery at fault.

If no effect can be obtained from the battery, the fault must be either in the *battery* itself, or in the *conducting wires*, or in the *electrodes*.

Most of the constant batteries which have just been described require a fresh charge only every two or three

months; and if the battery has therefore been charged a few weeks before use, it is not likely that the fault is in the instrument itself. It may be due to imperfect connection of the several pairs, as the plates or wires used for this some-

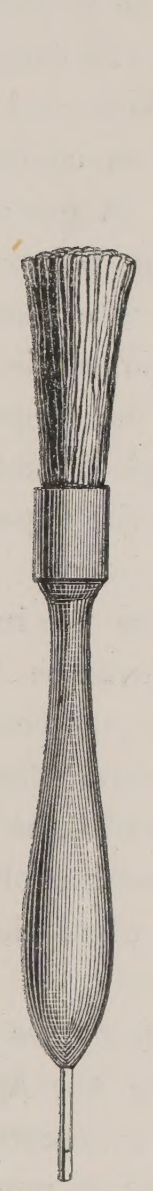

FIG. 84.

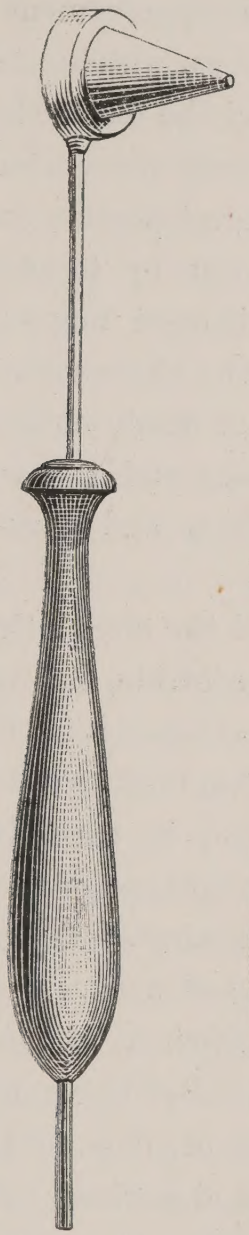

FIG. 85.

FIG. 86.

times get rusty or displaced; and where this is discovered it must be rectified. In summer the chemical decomposition which is going on within the battery is more active than in winter, and in those instruments which are not hermetically

closed the evaporation of water is sometimes so considerable that batteries which may contain the other chemical ingredients in good condition may yet refuse to act, unless a fresh supply of water be added from time to time.

Another cause of disappointment may be a bad condition of the *conducting wires*, which establish the connection between the battery and the electrodes. Wear and tear soon spoils the ends of these wires, which often conduct imperfectly when their central portion is still in good condition. This may be found out by touching the polestuds of the battery with the moistened fingers, and afterwards connecting the rod-ends of the wires with the polestuds, and again touching the hook- or clamp-ends with the fingers. If the polestuds give a shock and the wire-ends do not do so, the fault is in the latter, and they must be repaired or replaced.

If the battery and the conducting wires are in order, and yet no action is perceptible, the fault must be in the electrodes. Sometimes there is insufficient connection between the electrodes and the hook- or clamp-ends of the conducting wires, and this should be carefully rectified, as it may produce sudden interruptions of the current (voltaic shocks) which are most undesirable, especially when the current is applied to the face and neck.

2. *Methods of Medical Application of the Continuous Galvanic Current.*—Before commencing the application of galvanism to a patient, it is advisable to ascertain whether the battery is in good working order or not, more especially when it is new, or when it has not been used for some time. This may be done: (*a*) by interposing a tangent galvanometer into the circuit, when the deflection of the needle will tell the presence and power of the current which traverses it; (*b*) by immersing the ends of the conducting wires in water, when the bubbling up of hydrogen gas at the negative pole,

and the blackening of the wire at the positive pole, will give a similar indication ; (*c*) by electrolysing a solution of iodide of potassium and starch, when a blue colour will be produced at the positive pole ; (*d*) by the operator applying the lowest degree of galvanic power which he has at his disposal to his tongue, and the highest to the back of his hand. The last test is not only the readiest, but also the most important, as no other experiment gives a better hint for the selection of the galvanic power to be used in cases of disease.

Another point of importance is that, on first applying the current to a patient, a very low degree of power should be employed. Patients are often in fear of 'shocks,' and nothing soothes their trepidation more than the perception of a slight and pleasant sensation, instead of a severe and painful one, which they had been expecting. Moreover, it is by no means necessary for therapeutical success to employ a current which is so strong as to cause distress.

It may be laid down as a general principle that a feeble current, used for a short time, produces the greatest therapeutical effect. A very powerful current almost always does harm instead of good, and more especially so when it is applied for a considerable length of time.

A question which has been chiefly mooted by Brenner and his followers is, whether the effects of galvanisation are owing to the current in its entirety, or whether each pole has a separate effect, and whether this is the only effect that is produced? Brenner takes the latter view, and has thereupon built the somewhat shaky structure of the *polar method.* Far more convincing proofs than have hitherto been brought forward, will be necessary to convince us of the correctness of Brenner's views, which seem to us to be physically as well as physiologically untenable.

I now proceed to describe the mode in which the con-

tinuous current should be applied to the different organs of the body.

a. *Galvanisation of the Brain.*—If it be intended to send the current through both hemispheres, three different modes of application may be used: *a*, one electrode is directed to the forehead and another to the occiput; *b*, one to the left and one to the right temple; and *c*, one to the left and the other to the right mastoid process. If, however, only one hemisphere is to be galvanised, as in certain cases of hemiplegia, it is best to put one electrode over the eyebrow and the other to or near the mastoid process of the same side. With regard to the direction of the current, Benedict has recommended to place the anode to the cervical spine, and the cathode to the right or left side of the forehead. I do not think that this direction should invariably be followed, since I have found that it had better be determined by the sensation experienced by the patient. If, for instance, the patient should complain of a feeling of fulness, pain, or weight and pressure on the forehead, it is advisable to apply the anode there; but if such sensations are experienced at the occiput, the cathode in front is preferable. Where the patient does not complain of the head, that direction should be chosen which appears to do most good.

In persons who are very sensitive to electricity, I have not unfrequently discovered that the application of the negative pole to any part of the head or face did harm, by producing irritation. In such cases I use the positive pole alone to the head or nape of the neck, and place the negative at some distant part, e.g. to the palm of the hand, or the pit of the stomach. This application is easily borne, and often most effective. A current of more considerable power should in such instances be used than where both poles are applied to the head, as the palm of the hand and the skin of the abdomen are but poor conductors of electricity.

Benedict has justly laid stress upon the necessity of *short* applications ('never more than half a minute'). Meyer recommends an application of two or three minutes' duration; but this is for some cases too long. I am in the habit of employing the current from thirty to ninety seconds at a time. The result of the first or second application generally gives the clue as to what length of time the application should last: if the shortest time seems to answer, it is not necessary to try a longer one, as sometimes the benefit already obtained is thereby counterbalanced. A current of from ten to twenty cells of Muirhead's battery is all that is required. That application, where only the anode is at the head or neck, may in certain cases be continued for five minutes with advantage.

A powerful continuous current applied to the brain in the way just described may produce giddiness, fulness and pain in the head, sickness, vomiting, blindness, and attacks of cerebral hæmorrhage, followed by general convulsions and paralysis. The same symptoms may be caused by the too prolonged application of a feeble current. *Sapienti sat.*

M. Cyon,[1] the able teacher of physiology at the University of St. Petersburg, is strongly opposed to galvanisation of the brain, thinking that the cases must be excessively rare in which it is possible to diagnose the seat of any disease of the brain; that even where this could be made out, galvanic irritation of the brain could hardly be of any advantage, even in a small proportion of those excessively rare cases; and that in the infinitisimal proportion of such cases where any advantage might be expected from it, the irritation could not be localised in that portion of the brain which would appear to require it. These reasons appear to us more those of a physiologist than of a physician. A physician who has clini-

[1] Principes d'Électrothérapie. Paris, 1873, p. 192.

cally and pathologically studied neurotic affections in a tolerably large number of cases, will, as a rule, not find any insurmountable difficulties in localising cerebral affections with a great degree of accuracy; while a physiologist would no doubt be entirely baffled under such circumstances. Cyon's second reason appears to us equally inconclusive; since we have often found that in cases of cerebral exhaustion owing to deficient nutrition of the brain, and also in paralysis and impairment of speech from softening, the use of a gentle current guided through the suffering cerebral substance produces excellent results. The third argument advanced by Cyon, viz. that it is impossible to localise the current in that portion of the brain which appears to require it, may also be easily disposed of. *Provided a gentle current be used for a short time*, the flow of it through healthy portions of the brain does not do any harm, while it may do a great deal of good to those diseased parts, the nutrition of which requires a stimulant. In the same way, a dose of ammonia and brandy taken by a healthy man will not influence his condition perceptibly, while it may save the life of a patient sinking from collapse.

Cyon is entirely mistaken in supposing that a feeble current cannot exert the least action upon the brain, on account of the colossal resistance offered by its substance and the cranial bones. We have seen (p. 69) that the brain is easily traversed by a feeble current applied to the cranial bones, and clinical experience shows that an 'excessively powerful' current is not only dangerous, but utterly unnecessary. Cyon's advice, therefore, 'to desist altogether from a direct treatment of the brain,' lacks not only a physiological but also a clinical basis.

b. *Galvanisation of the Spinal Cord.*—That the cord is easily reached by the continuous current, has been shown in a previous chapter (p. 72). Where it is intended to influence

the whole of the cord, one electrode is directed to the upper, and the other to the lower portion of the spine; but where there are decided indications that a particular portion of it is suffering, while other parts of it are healthy, the current should be directed to the former. Where one or several vertebræ are painful or sensitive to pressure, they should be brought under the influence of the anode. Galvanisation of the spinal cord is generally continued for five minutes.

It is best to regulate the intensity of the current by the sensations experienced by the patient. If pain be caused, the current is as a rule too strong; but it is necessary to produce plainly perceptible feelings of pricking and heat. Some patients bear only ten or fifteen cells, while in others from fifty to sixty are required. If it is found that a gentle current has no effect, the power must be increased; and provided the seat of the disease is not in the cervical spine, this can be done without harm. Certain cases of ataxy and amenorrhœa resist a gentle current, but yield to a powerful application.

Cyon [1] is of opinion that a gentle current is under any circumstances better than a powerful one for acting on the spinal centre. He reasons that, as the conductivity of osseous matter is at least ten times less than that of the cord, the intensity of the current in the cord must be ten times greater than it can be in the vertebræ; i.e. that the current will be propagated with preference in the cord, where it arrives by the openings between the apophyses, inasmuch as the ligaments which close these openings have about the same conducting power as the cord itself. If the cord were surrounded by a better conductor—for instance, muscular tissue—it would, according to the same physiologist, be necessary to employ a very high galvanic power to affect the

[1] Loc. cit. p. 197.

cord; for the greatest portion of the current would travel along the better conducting tissue. These considerations are wonderfully ingenious, but not particularly practical; and they are not corroborated either by physiological experiments or by clinical experience. It is quite true that a feeble current applied to the spine will enter the cord; but muscular tissue does in no way prevent the action of the current upon the deeper-lying structures. If Cyon's reasoning were correct, the bad conductivity of the skin would promote the arrival of the current in the tissues beneath it. It is, however, an incontestably-established fact, that the current arrives more easily in the nerves and muscles if the conductivity of the skin be improved by moistening it, or by other means. Cyon, to be consistent, should therefore recommend the current to be applied to the spine by dry conductors, in order to get a larger quantity of electricity to traverse the cord; yet in the same passage of his book he recommends to *moisten* the skin ('il faut aussi bien humecter la peau')!

The chief influence of the current applied to the spine must, in consonance with anatomical facts, be exerted upon the posterior columns and nerve-roots; and that this is so in reality is corroborated by clinical experience, which shows that diseases of the posterior columns of the cord are more beneficially influenced by galvanisation than those of the anterior columns. Portions of the current, however, unquestionably reach the anterior columns as well; moreover it is well known that the posterior roots have a considerable influence upon the nutrition of the anterior ones; so that anything that acts on the former, must also, to some extent, act on the latter.

Cyon recommends that galvanisation of the spine should be continued for from ten to twenty minutes at a time; but in the majority of cases five minutes will be ample. If Cyon's recommendation were ever acted upon in practice, it would

be necessary to employ unpolarisable electrodes, as otherwise the skin would soon be in such a condition as to render further applications impossible. In using unpolarisable electrodes, however, an important element in the action of the current is eliminated, and the therapeutical results would therefore be less satisfactory than they might be otherwise.

Dr. Wilks[1] has, in a lecture recently delivered to the students of Guy's Hospital, made some very singular statements concerning the subject now under consideration. He says that the simple transmission of the current along the spine produces apparently no result; that it has yet to be discovered that a current flowing continuously through any part of the body has any effect either on the muscular or the nervous system; but that, as often as the circuit is opened or closed, one pole being on the upper part of the spine, and the other on the lower dorsal region, a sensation is experienced. Such statements would not deserve to be mentioned if they emanated from a less eminent teacher than Dr. Wilks. Suffice it to say that 'forsanque bonus dormitat Homerus.'

3. *Galvanisation of the Cervical Sympathetic Nerve.*—The different methods of galvanising the cervical sympathetic have already been described (p. 166). It has also been shown that a localised application of the continuous current to the cervical sympathetic in the living subject is impossible. Nevertheless the proceedings known as 'galvanisation of the sympathetic' are of considerable practical value; and it has been experimentally proved that that nerve is reached by the current, if the latter be applied in the manner described. We have therefore now to consider how far these proceedings may be therapeutically utilised.

The cervical sympathetic does not contain all the vasomotor nerves of the whole body, but only animates the

[1] British Medical Journal, January 1873, p. 29.

territory of the carotid artery, so that, by galvanising it, we can only influence the circulation in the ear, the eye, the face, and certain portions of the brain. It would therefore be foolish to expect, from isolated galvanisation of the sympathetic, any effect upon the nutrition of the upper or lower extremities. But we have already seen that by galvanisation of the cervical sympathetic, the depressor nerve and the spinal cord are also brought under the influence of the current. Irritation of the depressor nerve, according to Cyon, paralyses all vaso-motor nerves of the body, and may therefore cause any vascular spasm depending upon the sympathetic to disappear. This goes far to explain the unquestionable results which have been obtained in certain cases of wasting palsy, and other affections of the upper and lower extremities, by the proceeding known as 'galvanisation of the sympathetic.'

Cyon[1] expresses himself as follows concerning what we may expect from galvanisation of the cervical sympathetic alone:—'If we excite this nerve alone, we may cause a contraction in the small vessels of the head, and augmentation of pressure in the large vessels. This modification of the blood-vessels may be useful in so far as it may promote the absorption of effused liquids, and prevent further effusions. If we only use the polarising (electrotonic) effects of the constant current, we may increase or diminish the tonicity of the cerebral blood-vessels, and thus produce a modification of the pressure of blood in the brain. It is possible that this modification may in turn exert a salutary influence, either by determining the arrival of a larger quantity of nutritive material, or by suppressing vascular spasm, or removing thrombuses in cases of embolism, and thus easing the circulation. The effects produced on the brain may evidently cause other effects in other parts of the body.'

[1] Loc. cit. p. 206.

For galvanising the *vaso-motor nerves of the upper extremity* without acting at the same time on its sentient and motor nerves, the same observer recommends to place one electrode at the point of juncture of the second rib and the second dorsal vertebra, and the other at the point of emergence of the seventh dorsal nerve-root; since the vaso-motor nerves for the upper extremity leave the spinal cord with the third and seventh dorsal roots, and proceed to the brachial plexus, traversing on their way the dorsal sympathetic and the first dorsal ganglion. But where it is not intended to act exclusively on the vaso-motor nerves of the upper extremity, one electrode may be placed to the point corresponding to the dorsal sympathetic, and the other to the axilla. The patient should at the same time be directed to hold that extremity which is to be treated on the other shoulder, as thereby the shoulder-blade is displaced on the thorax, and it is easier to act on the lateral columns.

For localising the galvanic current in the *vaso-motor nerves of the lower extremity*, Cyon recommends to place one electrode in the region of the inferior dorsal apophyses, and the other on the lumbar apophyses, or where the sciatic nerve emerges from the pelvis. He advises the application to be continued for from ten to twenty minutes. The remarks made previously on this subject under the heading of 'Galvanisation of the Spine' apply here likewise.

Certain precautions ought to be taken in using the proceeding known as galvanisation of the cervical sympathetic. It is necessary, in the first instance, to use a very gentle current; and, secondly, to cause the opening of the circuit not suddenly, but gradually. If we open it rapidly, a disagreeable sensation of giddiness is caused, which frightens the patient, although I have never known it to do any actual harm. This can be avoided either by drawing one conductor very gently and slowly across the neck, away from

the stylomastoid fossa ; or, better still, by gradually diminishing the galvanic power which is being used, in the metallic circuit. If giddiness should be caused in spite of these precautions, and be accompanied with tinnitus aurium, the application has been either too long or too strong.

Diplegic Contractions.—This term has been proposed by Remak[1] for designating certain reflex contractions which he observed on using the continuous current in cases of progressive muscular atrophy and rheumatic gout, and which are, according to him, caused by the action of the current on the sympathetic. Remak found that the two points from which these contractions are most easily elicited are the auriculo-maxillary fossa of the opposite side, corresponding to the ganglion cervicale superius, which should be under the influence of the anode having a small surface, the sixth cervical vertebra of the same side being at the same time under the influence of the cathode, with a large surface. Sometimes the second point is lower down on the spine than the sixth cervical vertebra; and Remak has therefore distinguished several zones, viz. the *cervical zone*, which is the spine above the fifth cervical vertebra; the *upper dorsal zone*, which goes from the fifth cervical to the sixth dorsal vertebra ; and the *lower dorsal zone*, from the sixth dorsal vertebra downwards to the sacrum, or even to the lower extremity. According to the same observer these contractions are more easily produced in recent cases than in such of long standing.

Fieber[2] agrees with Remak in almost every particular, except in so far as he obtained diplegic contractions, not only with the continuous, but also with the induced current, in progressive muscular atrophy, rheumatic paralysis, lead palsy, and cerebral and spinal paralysis. They may continue

[1] De l'application, etc. p. 27.

[2] Berliner klinische Wochenschrift, 1868. No. 23.

beyond the time of the application, and resemble choreic movements.

Meyer [1] has observed diplegic contractions in an anæmic girl, with paralysis and atrophy of the upper extremities, in consequence of chronic arsenical poisoning; and found that they could be produced not only by placing the directors to the points indicated by Remak, but also by putting them to the right or left side of the spine, or one to the pit of the stomach and the other to the dorsal spine. It therefore appears that for causing these contractions the current need not act on the ganglion cervicale superius.

According to Benedict,[2] these contractions appear chiefly where there is increased reflex excitability throughout the system, and where the sympathetic is sensitive to pressure. This agrees with my experience, for I have observed them chiefly in hysterical patients, and have found that they could not be produced when reflex excitability had been diminished by treatment, as, for instance, after a course of bromide of potassium.

d. *Galvanisation of the Pneumogastric Nerve* may be resorted to in cases of asthma, spasmodic diabetes, and certain affections of the heart, and is so performed that the cathode is placed near the angle of the lower jaw on the carotid artery, and the anode to the manubrium sterni, on the inner edge of the sterno-mastoid muscle. The application should as a rule not exceed two minutes at a time.

e. *Galvanisation of the Roots of the Spinal Nerves* has been strongly recommended by Benedict, and is carried out so that the positive electrode is placed to the top of that portion of the spinal cord which is diseased, while the negative is slowly passed thirty or forty times down the sides of the vertebral column. The power of the current should be

[1] Loc. cit. p. 157. [2] Loc. cit. p. 69.

proportional to the sensibility of the patient and the result of each application. Where a neuralgic affection of the leg is believed to be caused by a lesion of the corresponding spinal roots, the anode is placed to the first lumbar vertebra, and the cathode passed down at the side of the spinous processes of the lumbar vertebræ and the sacrum.

f. *Galvanisation of the Motor Nerves and Muscles.*—For galvanising the motor nerves and muscles various methods are used. In some cases the cord is included in, while in others it is excluded from, the circuit. Where the cord is excluded, the anode is directed to a point of the skin where a nerve-trunk is easily accessible, and the cathode is applied to a more peripheral part. If it be intended to include the cord, the positive pole may be placed to the lumbar, dorsal, or cervical spine. Other things being equal, the effect is greater the nearer the part of the cord which is acted upon is to the medulla oblongata. It is commonly observed in cases of paralysis and anæsthesia of the lower extremities, that a peripheral application from nerve to muscle produces no contraction or sensation, even if a powerful current is used; that a slight effect is caused by including the *lumbar* portion of the cord, while decided muscular contractions and sensations ensue when the positive pole is directed to the *cervical* spine, more especially to the seventh cervical vertebra. The peripheral application should be used where the seat of the affection is peripheral; while in central affections a central as well as a peripheral application may be employed.

The directors are either held fixed on the skin, or they are moved about. The former method was by Remak called '*stabile*,' and the latter '*labile*' application. In the present work these two proceedings are termed '*continuative*' and '*intermittent*' application. Details on this subject will be found in the fifth chapter, while the anatomical relations of

the motor nerves will be mentioned under the heading of 'Faradisation.'

If the current is not felt, as may be the case on the extremities, when sensibility is very sluggish, it is advisable to use a concentrated solution of salt instead of ordinary water for moistening the electrodes, and where even that should not be sufficient, the limb should be rubbed with the flesh-brush or glove previous to the application. In a case of hemiplegia owing to softening, and complicated with elephantiasis of the paralysed leg, which I saw in consultation with Dr. Deakin, of Dromana, the current of fifty cells of Smee's battery was not perceived on the affected leg; while after the use of the flesh-brush, twenty cells were all the patient could comfortably bear. Blistering, which was formerly much in vogue, will therefore probably never be required.

g. *Galvanisation of the Olfactory Nerve* is so performed that an insulated sound carrying a conducting wire in its central canal, and having a free metallic end at either side (Fig. 79, p. 325) is introduced into the nasal cavity. The near end is then connected with the conducting wire of the negative pole, while the far end touches the ramifications of the first cerebral nerve. The circuit is closed by putting the moistened anode to the cheek. I have used this proceeding in some cases of anosmia with good results, and have generally let the current act for five minutes at a time. The power employed should be very low, as otherwise the optic nerve might be unpleasantly affected.

h. *Galvanisation of the Optic Nerve.*—The optic nerve may be galvanised from any part of the face or neck. If a mucous membrane—for instance, that of the tongue—be touched by one of the electrodes, the current is more easily transmitted to the nerve than when both directors touch the skin. In the majority of cases of amaurosis and weakness of sight, owing to insufficient nutrition of the optic nerve,

which I have galvanically treated, it has appeared to me that the best method was to put the anode on the closed eye, and the cathode to the palm of the hand, for about three minutes, and then to reverse the position of the electrodes and prolong the action for three minutes more, so as to put the nerve alternately into the condition of anelectrotonus and catelectrotonus.

i. *Galvanisation of the Gustatory and Glossopharyngeal Nerves* is appropriate in cases of loss of taste, and is carried out either by putting two metallic electrodes on the tongue itself, or by directing the current to the nerves mentioned, by pressing two ordinary moistened electrodes beneath the lower jaw.

j. *Galvanisation of the Auditory Nerve.*—In cases of nervous deafness and tinnitus aurium the application of the continuous current to the auditory nerve may be useful. The patient may be placed in the recumbent position, and have the external meatus filled with warm water, after which an insulated sound, with a metallic knob, connected with one of the poles of the apparatus, is held into the water, while an ordinary moistened electrode is placed in the neighbourhood. From ten to fifteen cells are generally sufficient, and voltaic alternatives often prove useful. The application may be intermittent or continuative, and should last two or three minutes at a time.

Another and readier way is to place a moistened sponge, connected with one of the conducting wires, into the ear, and an ordinary moistened electrode into the hand. Stöhrer has constructed a special ear-speculum electrode (Fig. 85, p. 327), which consists of a wooden handle traversed by a stout brass-wire, which projects at both ends of the handle. At the near end of the wire the conducting wire is fastened, while the far end carries an ear-speculum made of ivory, and carrying inside a strip of metal connected with the wire. A small piece of

moistened sponge is then drawn through the opening of the speculum, and made to convey the current to the membrana tympani, the other electrode being either in the hand or at the nape of the neck.

k. *Galvanisation of the Rectum.*—In certain cases of intestinal atony, especially where there is meteorism and tympanites, the continuous current often produces bracing effects superior to those of any other remedy. In such cases a rectal conductor is introduced into the rectum for a distance of four to six inches, the circuit being closed by the application of an ordinary moistened electrode to the abdominal parietes.

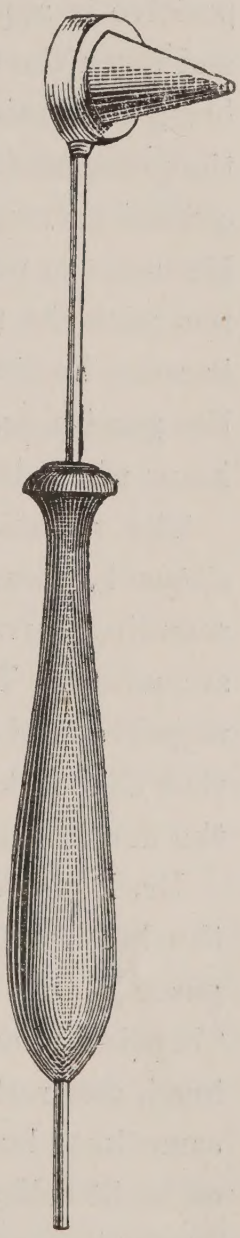

FIG. 87.

l. *Galvanisation of the Urethra.*—In cases of spermatorrhœa, and in chronic inflammation of the prostate, the application of the continuous current to the prostatic portion of the urethra is often followed by excellent results. The same proceeding has also been used for the cure of stricture of the urethra. The negative pole alone should act upon the urethra, and the circuit be closed by placing a moistened sponge connected with the positive pole to the groin.

m. *Galvano-puncture.*—As a rule, galvano-puncture is rarely used in the treatment of any but surgical diseases, the reason for this being that it is more painful than the ordinary application of moistened sponge-conductors to the uninjured skin. In obstinate cases, however, especially of pain, galvano-puncture produces decided effects after the percutaneous application has failed. The mode of proceeding will be described under the heading of 'Electrolysis.'

Central Galvanisation.—Dr. Beard [1] has lately proposed a method which he calls central galvanisation. He recommends that the negative pole be applied to the epigastrium (the patient holding it by an insulated electrode), while the positive is applied over the head, around the sympathetic, and down the whole length of the spine, in such a way as to bring the brain, the pneumogastric, the spinal cord, and all the prominent plexuses of the sympathetic—indeed, the whole central nervous system—under the influence of the current. He came to use this method, partly because he was dissatisfied with the results obtained by other methods, and partly because he found it difficult in many cases to determine the precise seat of the disease, and consequently did not know where the current should be localised.

The negative pole should be placed on the pit of the stomach, because it is well borne there, and because the descending current seems to act better in most cases than the ascending. The positive pole is less acutely felt than the negative, and is less irritating, and he thinks it not unlikely that this fact may explain the more satisfactory results of the descending current in central galvanisation.

Dr. Beard does not always make the applications all over the head, but sometimes merely on the forehead, gently passing the electrode from one side to the other; then 'baptises' the patient on the cranial centre, at the top of the head, and rests the pole there for about one minute, and sometimes longer. To the head he applies from two to six or eight cells, beginning with a weak current, and gradually increasing until an acid or metallic taste is perceived in the mouth. He regards the cranial centre as the most important region of the head in all electrical applications, and especially in central galvanisation. 'A current passing from that point

[1] 'New York Medical Journal,' October 1872.

to the epigastrium, traverses the centre of life—if life has any centre—and affects the sympathetic and the roots of the facial nerves.' The sensation produced by this application is different from that of any other application to the head. The brain requires only about one or two minutes galvanisation, and care should be taken to avoid sudden interruptions of the current.

The electrode is then passed down the inner border of the sterno-cleido-mastoid muscle, from the auriculo-maxillary fossa to the clavicle, for the purpose of affecting the pneumogastric and sympathetic. He usually makes the application on both sides, and from one to five minutes.

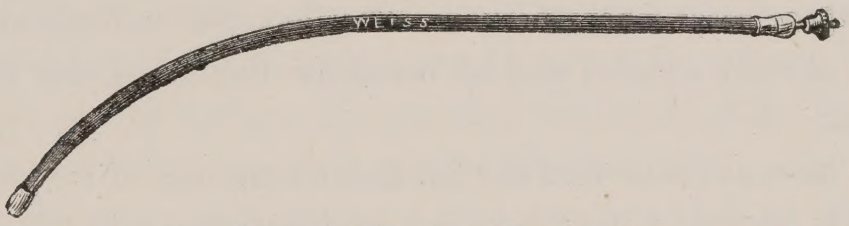

FIG. 88.—Urethral Electrode.

'In galvanising the spine, especial attention is given to the cilio-spinal centre, below the first and seventh cervical vertebræ. The electrode should also be passed the entire length of the cord by labile applications up and down. The back is not usually sensitive, and a strong current, from ten to thirty cells, can be borne without discomfort. The back may be treated from three to six minutes, and the whole length of the *séance* of central galvanisation ranges from five to fifteen minutes.

'All the preparation a male patient requires for central galvanisation is to unbutton the collar, remove the coat and vest, and slip off the whole clothing, so that free access can be had to the spine. A female patient may remove her corsets and slip up her under-clothing, or merely loosen the clothing at the neck and waist, so as to make room for an electrode to be passed down to the epigastrium, and for a

spinal electrode to be passed up and down the back. For the negative electrode at the pit of the stomach any electrode with a broad surface and an insulated handle will answer. For the positive pole, he prefers his adjustable electrodes, of different sizes. These can be passed under the clothing with great ease, and may be provided with flannel covers, that may be washed as often as necessary.'

Dr. Beard thinks central galvanisation chiefly suited for nervous affections, where, in spite of nervous exhaustion or perturbation, the muscular strength and the general nutrition are not much impaired; while he would reserve his proceeding of general Faradisation, which will be presently described, for those cases where nervous affections are accompanied by loss of body weight, and by muscular flabbiness and feebleness.

I have never carried out Dr. Beard's method in its entirety, partly because I have not been so dissatisfied with the results of the methods previously described, and partly because I have not so frequently felt uncertain about the nature and seat of the disease which I was treating. But I have, years ago, used experimentally applications to the head and neck with the anode, and to the epigastrium with the cathode. In several of the cases thus treated I found that disagreeable cerebral symptoms were produced by it during the application, and which sometimes continued for twenty-four hours or more afterwards. The patients had a general sensation of malaise and nervousness, headache, and a feeling of giddiness and confusion. This appeared to me most striking, when the head and the mastoid fossa were acted upon, and less so when the cervical spine alone was under the influence of the anode. I have therefore given up the application of the anode to the head or the mastoid fossa, and of the cathode to the pit of the stomach; but I use not unfrequently the application of the anode to the cervical or lumbar spine, and

of the cathode to the pit of the stomach, with advantage, more especially in cases where the symptoms are not very well defined, and where there is a low state of nervous power throughout the system.

III.—SURGICAL APPLICATIONS OF THE CONTINUOUS GALVANIC CURRENT.

Under this head are comprehended both the galvanic cautery and electrolysis.

1. The Galvanic Cautery.

a. *The Batteries.*—We have already seen that, for utilising the calorific effects of galvanism, a few cells with a large surface are the best, as the essential resistance of the circuit is insignificant in such an arrangement (p. 51). The batteries principally used for the galvanic cautery are the following:—

Middeldorpff's apparatus (Fig. 89) consists of four large cells of Grove's battery (*d* and *f*), contained in four different compartments of a wooden box. The cylinders of zinc are placed in cylinders of glass containing diluted sulphuric acid, and have a surface of 312 square inches. Inside the zinc are placed cells of unglazed porcelain, filled with nitric acid, for the reception of the platinum plates. Each plate consists of three parts, bent double, so as to form a star of six rays (*f m*), the surface of which amounts to 250 square inches. Both zinc and platinum are furnished with contrivances for fixing the conducting wires. In the centre of the box is the commutator (A), which contains eight small cups for the reception of mercury, which itself receives the conducting wires (*i*) coming from the zincs (ZZZZ), and platinums (PPPP), and fixed by means of a screw arrangement (*k m*). At the points *h*, *g*, the first platinum

and the fourth zinc wire merge into the wires *n*, *n*, which establish metallic connection (*oo*, *pp*) with the studs for inserting the conducting wires.

Middeldorpff's is a powerful apparatus, but it is very expensive and troublesome to manage; and it has therefore, on the whole, not found much favour with the profession. A

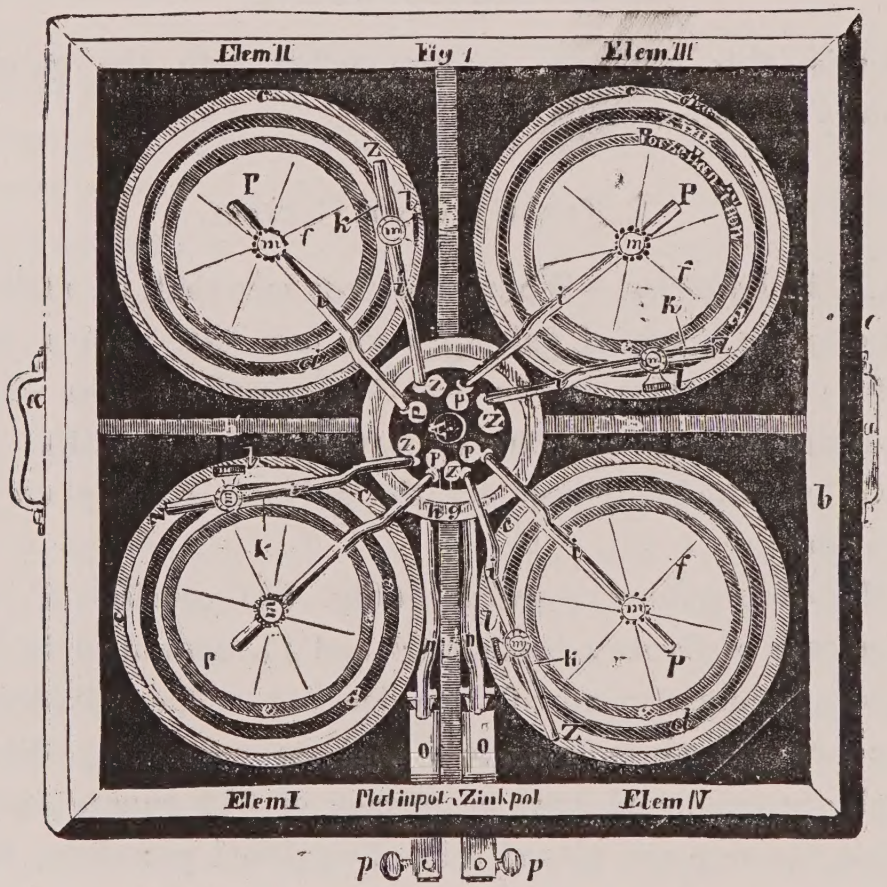

Fig. 89.—Middeldorpff's Cautery Battery.

thoroughly competent assistant is indispensable, as the nitric acid may easily enter into ebullition, and do great damage. Moreover, the fumes of the nitric acid are most irritating to the air-passages.

Grenet's apparatus (Fig. 89), which is generally used in France, but rarely, if ever, in England or Germany, is a modification of Bunsen's battery, and furnishes a powerful current. It consists of nine zinc plates and six carbon plates,

three plates of zinc being connected with two of carbon. The exciting liquid is one part of sulphuric acid, with five parts of water, and 100 grammes of bichromate of potash dissolved in a litre of the acidulated water. This battery does not act unless the liquid is kept in a state of constant agitation by blowing air into it with a pair of bellows. After this has been done for a few seconds, the wire is rendered incandescent. Grenet's apparatus is very bulky, and the arrangement of liquid and plates complicated; more-

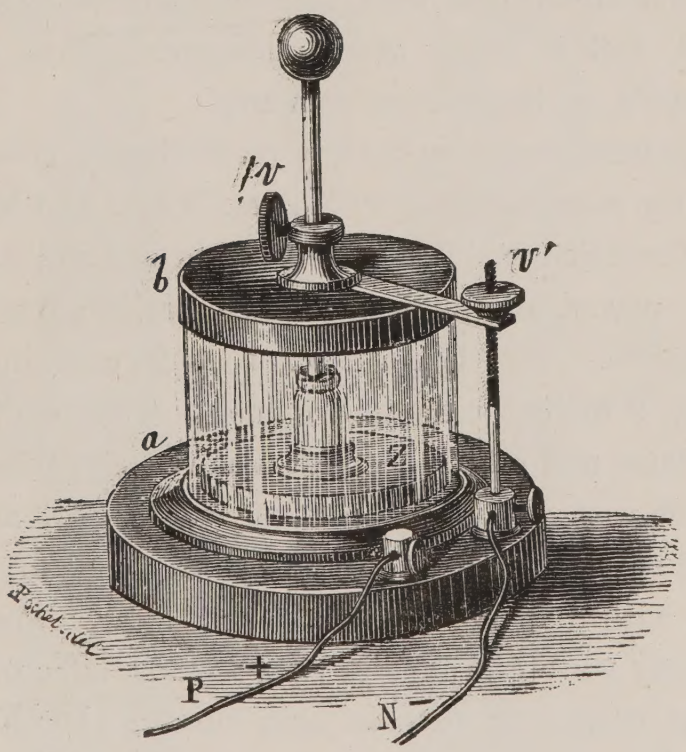

FIG. 90.—Grenet's Apparatus.

over, it generally requires to be discharged after having been used, or it will not easily act again, and the work of the assistant who has to manage the bellows is very heavy. These are the chief reasons why the apparatus has not found much favour out of France.

In both Middeldorpff's and Grenet's instruments it is not easy to regulate the degree of heat produced, which is nevertheless of the greatest importance, because if white heat be

attained, there is danger of hæmorrhage; and if too little heat be evolved, the instrument is more or less inert.

Professor von Bruns, of Tübingen, uses a battery composed of zinc and iron and charged with strong nitric acid. It is very powerful, but requires close watching, as the acid easily enters into ebullition and destroys all the furniture and other things with which it may happen to come in contact.

Stöhrer's galvanic-cautery battery consists of six pairs of zinc and carbon charged with diluted sulphuric and strong nitric acid, and is much more manageable than Grenet's, Middeldorpff's, or Bruns's instruments.

A nice galvanic-cautery battery on Stöhrer's principle has been recently manufactured by Messrs. Meyer and Meltzer, of Great Portland Street. It combines lightness and portability with great power, and is much more easily adjusted than other batteries. The box in which it is contained is 40 inches long, 9 inches wide, and 7 deep. This contains not only the plates and electrodes, but also two stoppered bottles for the acids with which the battery is charged, and which are diluted sulphuric acid (1 in 8) and nitric acid.

A lever, with dial plate in front of the box, allows the use of the battery while the box is closed, thus effectually preventing the escape of nitrous acid fumes. Dr. Kidder, of New York, has constructed a battery (Fig. 94, p. 354), which resembles that of Meyer and Meltzer. The electrodes are an écraseur, cutting loops and porcelain cauteries (Fig. 95).

Messrs. Krohne and Sesemann have lately constructed a galvanic écraseur, which is highly spoken of by those surgeons who have used it. It consists of the handle, *a*, which carries the two wires that have to transmit the thermic influence to the platinum loop, *d*, and are at their other end connected with the battery wires, *g*; *c* are the cannulæ, through which the wires pass after they have left the handle;

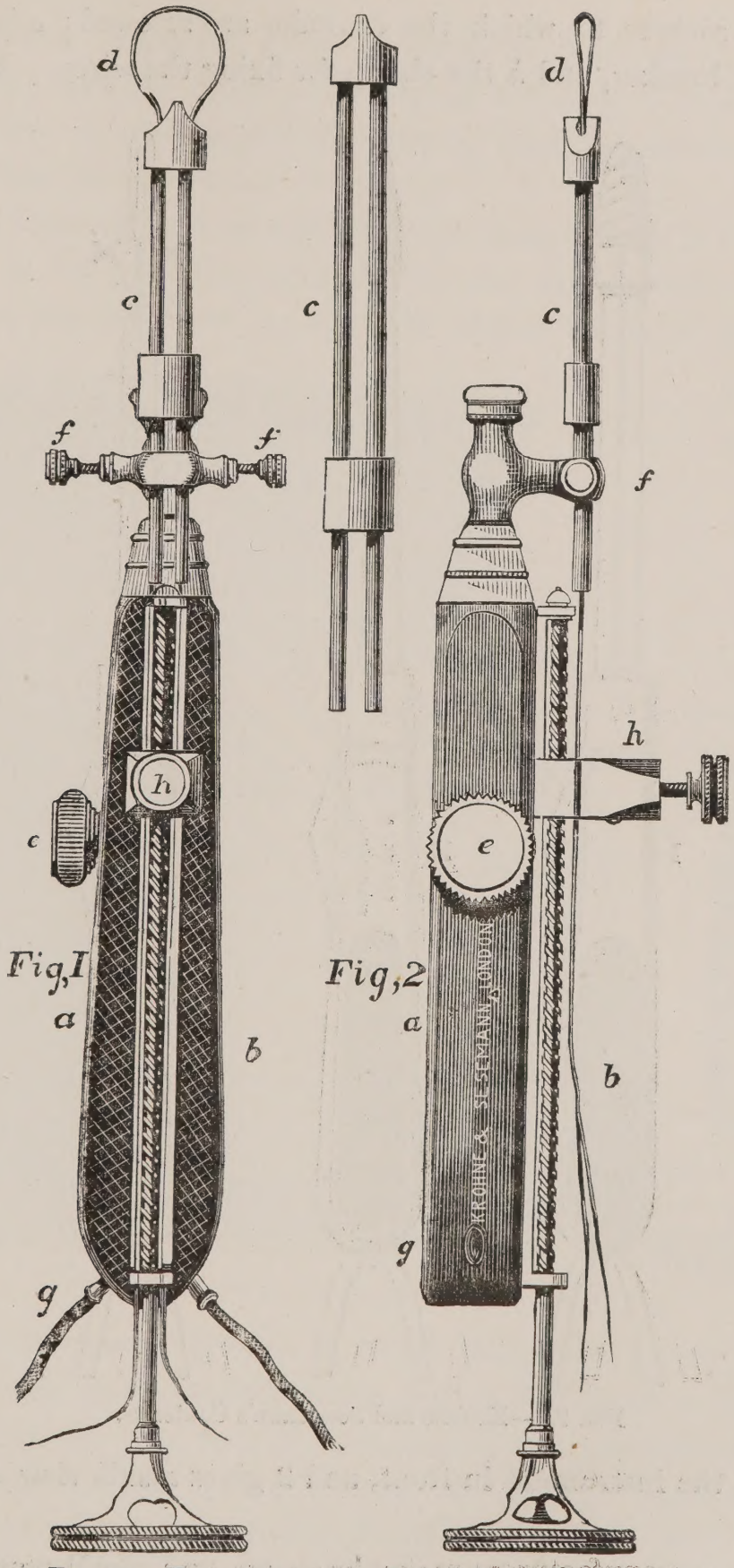

FIG. 91.—Krohne and Sesemann's Galvanic Écraseur.

f f the sockets to which the cannulæ are screwed; *e* is the contact breaker, and *h* the clamp for fixing the wires. No. 1

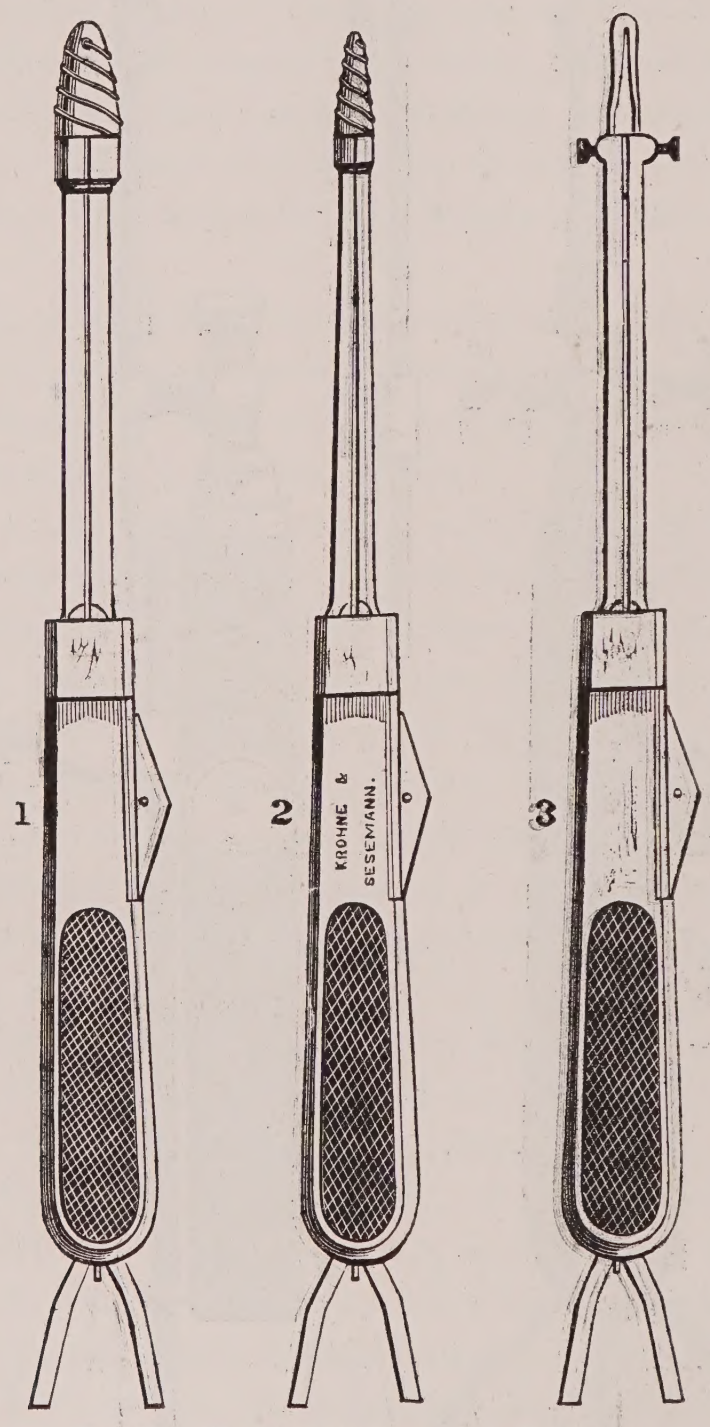

Fig. 92.—Krohne and Sesemann's Cauteries.

shows the instrument in front, and 2 gives a side view of the same.

The same manufacturers make large and small porcelain

cauteries. Platinum wires of different shape and size may be fixed into the handle, for varying the mode of cauterisation, and on each handle is a sliding knob for making and breaking the current.

An important advantage of the galvanic cautery is that no pain is felt after the operation, for the extremities of the nerves are destroyed by it. The eschar which is former

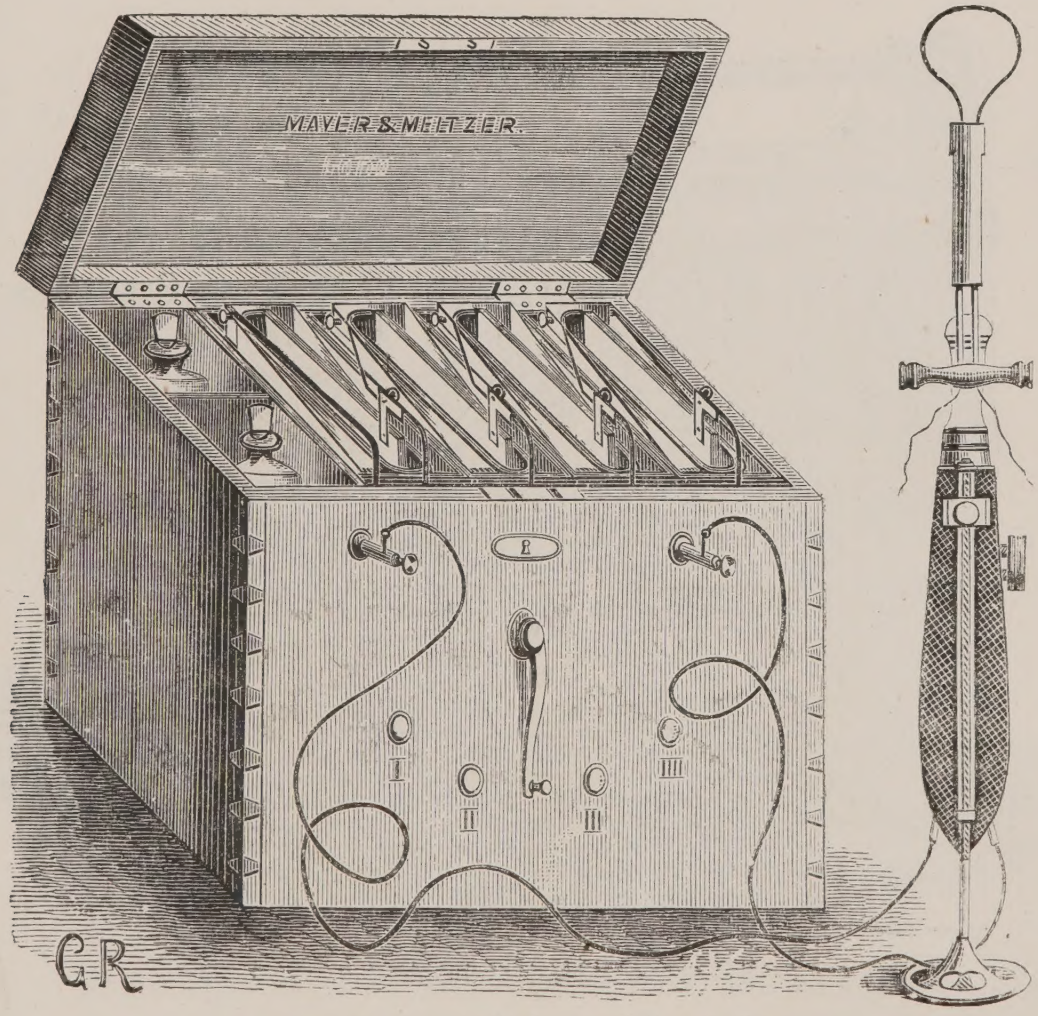

Fig. 93.—Meyer and Meltzer's Galvanic Cautery.

renders the wound invested by it less liable than a moist and granulating surface to miasmatic, putrid, and purulent infection; and one great source of mortality after operations is thus removed. Another advantage attending this mode of treatment is that, with a proper application of the heat, the vessels are occluded by clots, and hæmorrhage is impossible.

2. *Electrolysis.*—All batteries which have been described under the heading of constant batteries, for the medical application of the continuous current, may be usefully employed for the electrolytic treatment of surgical diseases. Stöhrer's electrolytic battery and Becker-Muirhead's are, however, the best for this purpose.

For conveying the galvanic current into the depth of the

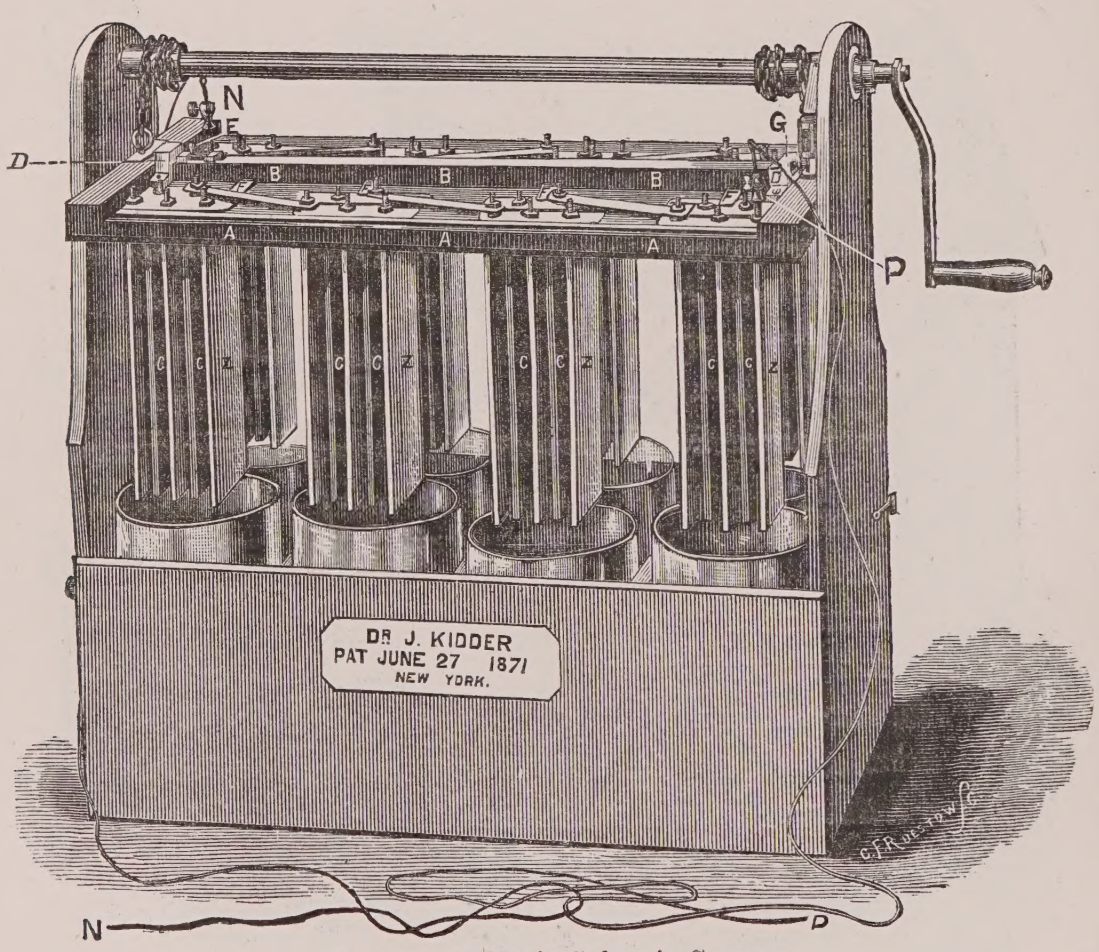

FIG. 94.—Kidder's Galvanic Cautery.

tissues, fine needles of gold or gilt steel are used for the negative pole, the circuit being closed by placing a moistened sponge connected with the positive pole outside on the skin. Most of the other instruments are modifications of the needle. I have used conductors from which two, four, six, and eight needles are made to branch off, to suit the

requirements of different cases (Figs. 98, 99, 100, 101). Sometimes circular-shaped conductors are useful (Figs. 102 and 103). For the treatment of ulcers, conductors with a larger surface are better suited; viz. blunt blades (Fig. 104), and round plates of different size (Fig. 105). All these conductors are made of gold or gilt metal, and insulated by ebonite.

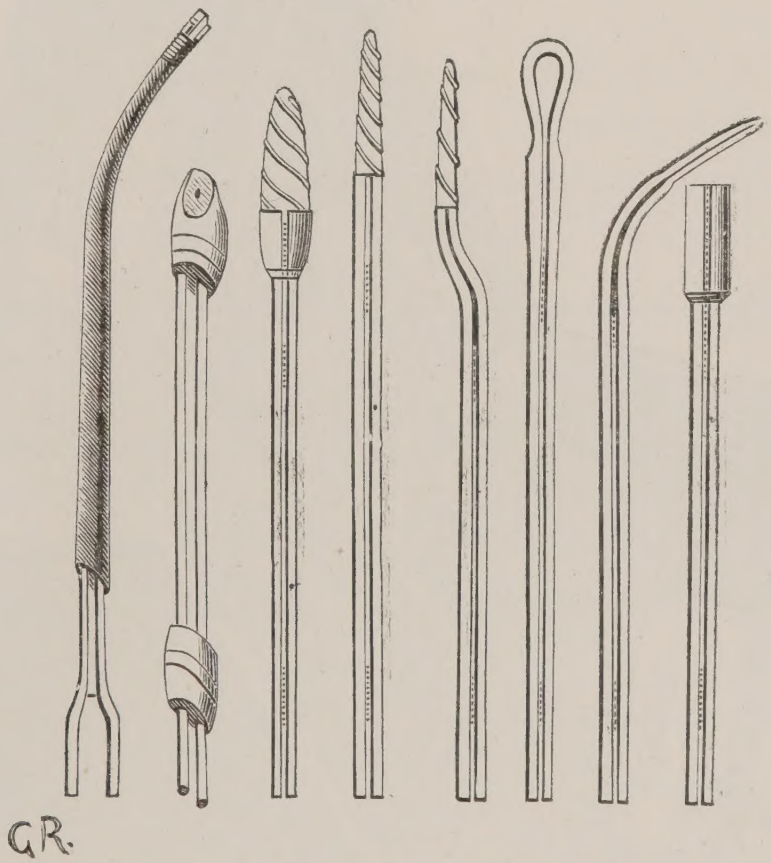

FIG. 95.—Meyer and Meltzer's Cauterisers.

The electrode, however, which is most universally useful is the *serres-fines conductor* (Fig. 106), which allows the introduction of from one to six or more needles *ad libitum*, and in any direction that may be required. It consists of a conducting wire, which at its end is made to branch off into six or more conducting wires of equal diameter, the ends of which are connected with serres-fines, by means of which the heads of the needles may be grasped after their introduction

into the substance of the tumour. Single needles are introduced more readily into the depth of the tissues than connected rows of needles; besides which, by means of this instrument, the needles may be introduced in any direction

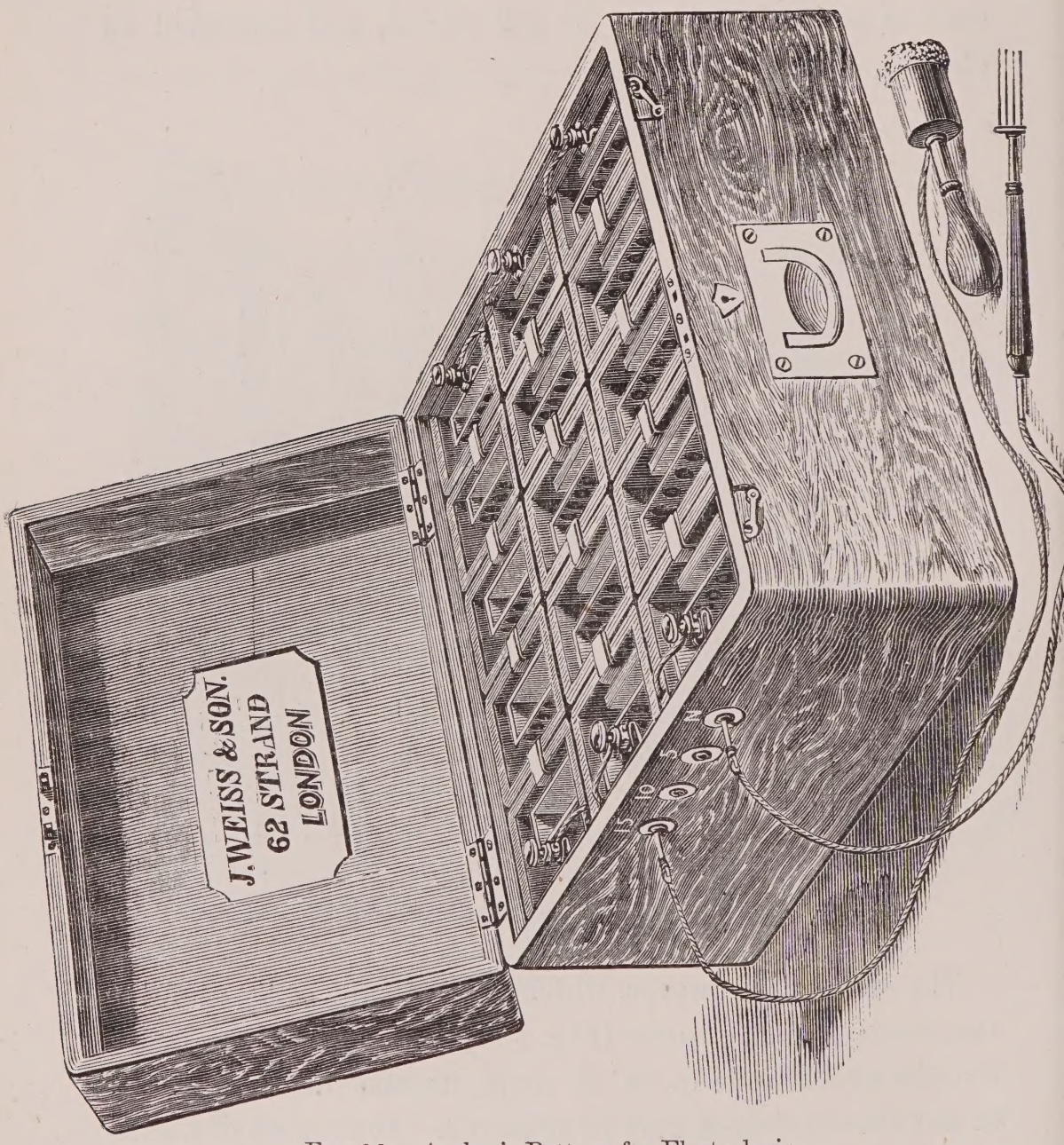

Fig. 96.—Author's Battery for Electrolysis.

that may appear most suitable, which with fixed rows of needles is not so easily practicable. Dr. Beard has somewhat modified the needle-holder, as shown in Fig. 107.

The introduction of needles through the skin must always be unpleasant to the patient; I therefore recommend practitioners to render the skin insensible to pain by means of ether spray before introducing them. Some patients are intolerant of ether, and represent it as very unpleasant, not so much, perhaps, at the time of its first application as

FIG. 97.

afterwards, in the period of reaction, when the frozen skin returns to its normal condition. Sometimes the skin remains red and peels off after a single application of ether, but in most cases the spray is well borne. I should, however,

FIG. 98.

FIG. 99.

FIG. 100.

FIG. 101.

FIG. 102.

FIG. 103.

FIG. 104.

FIG. 105.

Author's Electrolytic Electrodes.

be very glad to have at my disposal some other ready means for rendering the skin insensible, and which would be less irritating than ether. I am informed that in America a hydro-carbon, called rhigolene, is now extensively employed for producing local anæsthesia. It is said to be free from the effects inherent to the ether; but, as it also acts by producing intense cold, I cannot see why it should have any advantage over ether, for it is not so much the peculiar kind

of hydro-carbon employed as the cold which produces the irritation. Highly sensitive patients, however, may be placed under the influence of chloroform, or bichloride of methylene.

The electrolytic application itself is not painful, even if a considerable power be used. It is, however, necessary to begin with a low degree, and only gradually to increase it. By

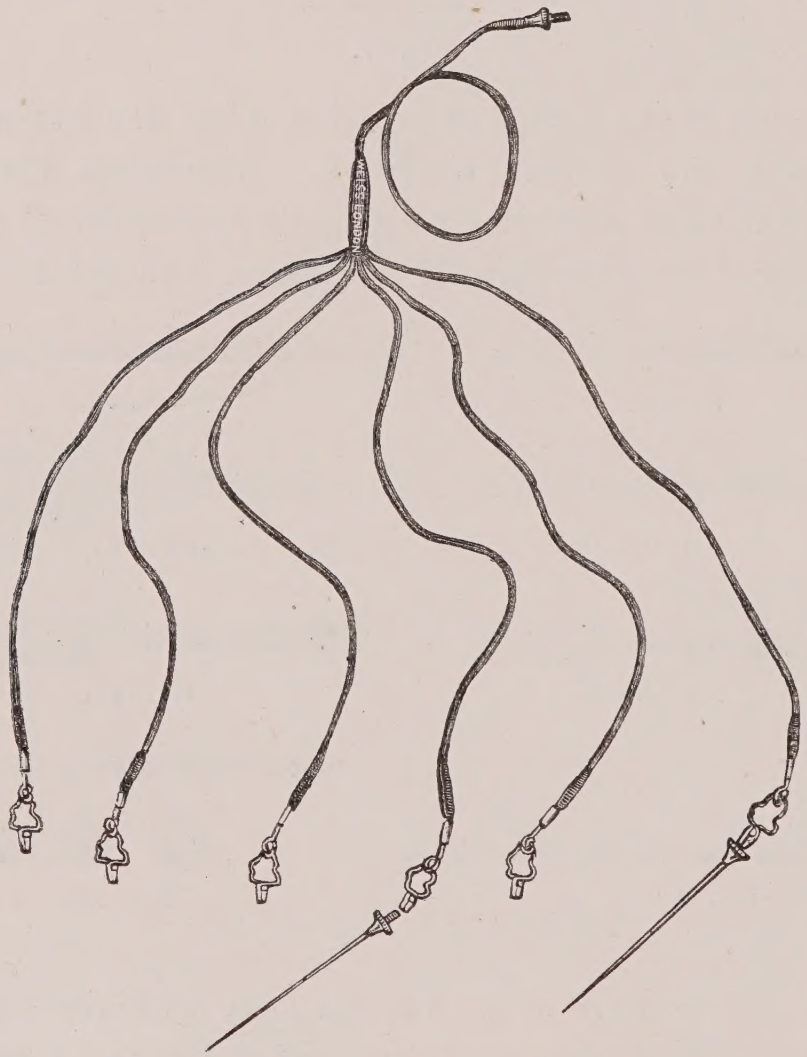

FIG. 106.—Author's Serres-fines Conductor.

proceeding thus the internal parts are gradually benumbed, and what might at the first moment have been felt as a severe shock gives no unpleasant sensation if this precaution be adopted. The benumbing effect of the galvanic current is, however, only produced where the current is applied inter-

nally; outside, where the positive pole is used, a sensation of heat and pricking is felt during the whole time of the application.

Most practitioners who have practised the electrolytic treatment have followed my recommendation to use only the cathode for the internal application; but several have used the anode as well in this manner. Amongst the latter Prof. Groh,[1] of Olmütz, deserves special mention. He uses Frommhold's battery (p. 314), which consists of zinc and platinised lead, and resorts either to a powerful current

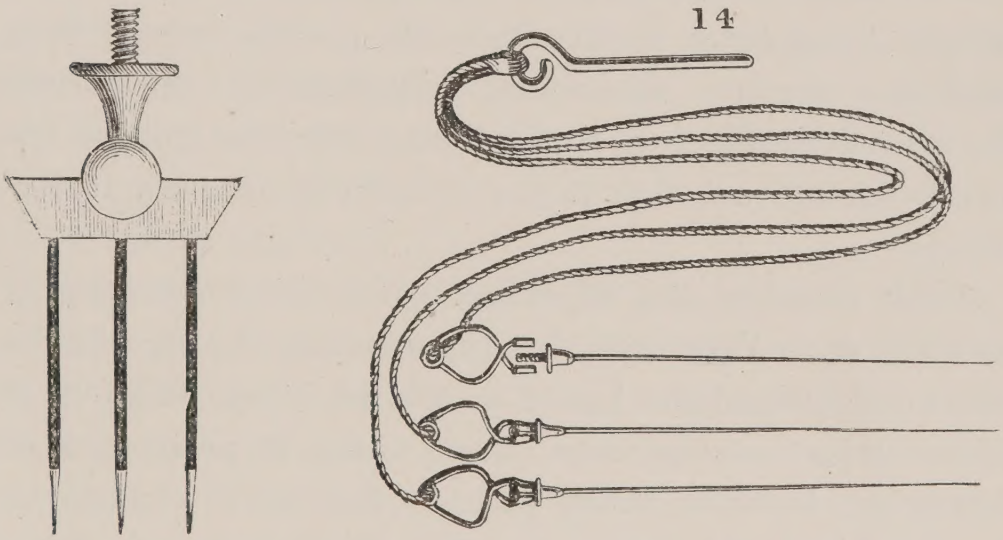

FIG. 107.—Other forms of Needle-holders.

applied for a short time under chloroform, or to a gentle current applied for days and nights consecutively. The needles employed by him are of steel, zinc, or platinum; and he finds it advantageous, where the parts which are to be destroyed are highly vascular, to use zinc needles which are dissolved at the positive pole by the nascent chlorine, so that there is not only primary, but secondary, electrolysis. The eschar at the positive pole looks under these circumstances like one produced by chloride of zinc paste; viz. it is

[1] Die Electrolyse in der Chirurgie. Wien, 1871.

greyish-white, firm, and dry. At the negative pole there is a rapid development of foam (hydrogen), which generally appears white, and more rarely brownish-red—the latter chiefly where the tissues are very vascular. The tissues become more tense by the quantity of gas which is set free, and the epidermis or mucous membrane becomes raised; discoloration of the tissues appears at first around the needles, but afterwards at a distance, and they assume a dark brown or livid tinge. Where this is distinctly perceptible, there is generally so much destruction caused that the tissues do not recover themselves after the application. Prof. Groh thinks it important to introduce the positive needle first, and the negative afterwards, inasmuch as the former becomes so firmly glued to the tissues after the current has commenced to act, that it is very difficult to push it forwards.

Groh considers the following to be the *advantages* of electrolysis:—Very extensive tumours may by its aid be destroyed without the loss of a drop of blood, which is of great importance in cases where there is prostration of strength. In three of his patients the use of electrolysis enabled him to do without resection of the lower jaw, which otherwise would have been necessary, and would have given rise to great disfigurement. In a case of cancer of the rectum, where subcutaneous injection of morphia produced only slight and temporary relief of the intense pain, and where there was a most offensive smell from the ulceration, both fetor and pain disappeared after the first electrolytic operation. In a case of epithelioma of the lip, where the right submaxillary gland was considerably swollen, this swelling was dispersed a few days after one electrolysis. Finally, all cases progressed favourably, without any bad accidents. The pain never continued beyond the application itself; there was only slight local and general reaction; the

eschars which had been formed were rapidly thrown off; there was copious granulation, and such an amount of cicatricial contraction as to cover the loss of substance caused by the removal of the growth.

The *drawbacks* of electrolysis are, that the batteries are expensive; that it is not always easy to introduce the needles so as to destroy as much as possible in the shortest time; and, where extensive tumours are to be destroyed, the applications must be frequently repeated, or prolonged for a considerable time. Groh thinks that surgeons will gradually find special indications for electrolysis as for any other operative procedures. Where the knife is the more simple instrument and equally devoid of danger, they will not think of resorting to electrolysis; but will use the latter where it either appears to offer special advantages, or where no other means can be employed.

In our own opinion the subject of electrolysis is still in its infancy, and requires a great deal of further elucidation by physiological and therapeutical experiments. One unquestionable advantage of this treatment is, that there is no danger of shock, and that the patients can, while it is carried on, pursue their ordinary avocations just as well as before. Our present experience seems to point to the conclusion that for tumours with soft contents only the cathode, and for those with hard contents both the cathode and anode, should be employed.

Diseases in which the electrolytic treatment proves chiefly valuable are tumours, serous effusions, strictures, and wounds and ulcers.

Dr. Golding Bird has recommended the prolonged local application of a single galvanic pair, to produce the effects of a moxa, in cases where a persistent discharge from some part of the body is required. The *galvanic moxa* is employed in the following way:—The cuticle is raised on

two points of the body by means of blisters, one being placed a few inches below the other. A piece of zinc foil is then applied to the one from which the discharge is required, and a piece of silver to the other, both metals being connected by a copper wire, and covered with a plaster. If the zinc plate be raised a few hours after the circuit has been established, the surface of the skin looks whitish, as if chloride of zinc had been applied to it. In 48 hours an eschar is produced, which begins to separate four or five days afterwards. The eschar is formed by the electrolytic action of the continuous current, in consequence of which the fluid effused on the surface of the blister is decomposed, sodium being set free at the silver plate, where by oxidation it rapidly becomes soda; and chlorine being evolved at the zinc plate, where, consequently, chloride of zinc is formed. The chloride of zinc, originated by electrolytic action, produces the sore, which discharges pus freely if a common poultice be applied to it. While this process is going on, the patient seldom complains of pain; probably because the caustic acts in infinitely small portions upon the skin, in proportion as it is liberated. The galvanic moxa is now rarely used, as cases 'where a persistent discharge from some part of the body is required' only rarely present themselves in practice. I have never seen one.

Medical Application of Induction Currents, Electro-Magnetism, and Magneto-Electricity.

(C) FARADISATION.—I. *History of it.*—The discovery of induction currents (1831) caused a new era in the medical application of electricity. The use of the voltaic pile had at that time been completely abandoned; constant batteries for medical use were not in existence; and the striking pheno-

mena produced with small and handy induction machines gave rise to the belief that at last the true medical electricity had been discovered.

The first induction apparatus suited for medical use was constructed by M. Pixii; the first physician who employed induction currents for therapeutical purposes was, according to German authors, Dr. Neef, of Frankfort, while M. Tripier ascribes this merit to M. Masson, of Paris; it was, however, undoubtedly M. Duchenne, of Boulogne, who, by his able electro-physiological researches on the functions of the muscles, gave the greatest impetus to the study of medical electricity in our time. Induction machines for medical use, both volta-faradic and magneto-faradic, were afterwards constructed by Messrs. Saxton, Clarke, Keil, Stöhrer, Breton, Du Bois-Reymond, Horne and Thornthwaite, Duchenne, Legendre and Morin, Siemens and Halske, Bernard, Baierlacher, Gaiffe, and many others. In the older of these machines all the conditions necessary for therapeutical application were not united; for in most of them only the current induced in the second wire could be utilised, and the intensity of the current, as well as the greater or lesser rapidity of the intermittences, could not be well regulated; while in those of more modern construction the necessary qualities are generally found combined.

II. *Induction Machines for medical use.*—In this place I shall first discuss the qualities which every faradic apparatus should possess if it is to be used for therapeutical purposes; after which a short description of those instruments will be given which are principally employed by medical men at the present time.

The question has been often asked whether the apparatus should be a volta-faradic or a magneto-faradic one. Both of them have had their panegyrists and adversaries.

The alleged inconveniences of volta-faradic machines,

in which the current is induced by a galvanic pair, are that they are expensive; that troublesome manipulations, involving loss of time, precede and follow the use of the machine; that this is not ready to act at a moment's notice, as it requires charging and discharging; that acids are necessary for inducing the current, whereby not only the battery but also the coil are gradually spoiled; while, on the other hand, magneto-faradic rotation machines are praised as cheap, always ready to act, and not requiring acids for their use. The objections to volta-faradic instruments which have just been mentioned are, however, not applicable to the more recently constructed machines, as they are generally not expensive, ready to act at any time, without charging or discharging, and may, with some little precaution, be kept perfectly clean and in good order.

The chief inconvenience connected with the use of magneto-faradic machines is that the operator requires an assistant to turn the handle connected with the endless chain of the apparatus, which puts the soft iron armature in rotation. This inconvenience, which is especially felt whenever prolonged applications are necessary, may, it is true, be avoided by the substitution of clock-work; but by this the rapidity of the intermittences cannot be so easily regulated.

Another drawback to the magneto-faradic current is that the sensation produced by it is far more unpleasant than that caused by electro-magnetism, which is due to the circumstance that the current induced by voltaic electricity rises at once from zero to its maximum, and then as quickly falls back to zero; while the variations in the density of the magneto-faradic current are much slower. The latter begins when the soft iron armature is withdrawn from the pole of the permanent magnet, reaches its maximum when the armature is between the two poles, and is finally reduced to zero when the armature arrives at the opposite pole of the

magnet. The volta-faradic current acts, therefore, more thoroughly on the motor nerves and muscles, and less disagreeably on the sentient nerves, while the magneto-faradic current has a more jerking and spasmodic effect on the muscles and sentient nerves. If applied to the face the latter has a slight but decided action on the retina, which is not affected by the volta-faradic current, unless this has a very high tension. The magneto-faradic current is perhaps more useful in rheumatism and weakness of sight than the volta-faradic: and before the continuous current was reintroduced into practice, magneto-faradism was most suitable for those affections; but now we should always employ galvanisation rather than faradisation in such cases. At the present time, therefore, magneto-electricity is, strictly speaking, not required for medical practice, although it may still find a sphere of usefulness where no better instruments can be procured. It is at present much in favour with the public, not only on account of its cheapness, but also because anybody is clever enough to turn a handle, but not sufficiently so to charge a battery.

On the whole it may be said that magneto-electricity, as furnished by the rotatory apparatus, has disappeared from medical practice, and is only used by those who must act with cheap instruments. Good magneto-electric machines can be had for from 15*s.* to 20*s.*, where most good electromagnetic machines cost 4*l.* to 6*l.* Tolerably good electromagnetic machines are now, however, likewise manufactured very cheaply. Thus, a small Gaiffe's sulphate of mercury induction apparatus can be had for 23*s.*; and the imitations of Gaiffe, which are sold by Messrs. Zimmermann, Fen Court, Fenchurch Street, London, go into small fractions of a pound, with which not even the cheapest magneto-electric machines can compete. On the whole, it may be said that in this, as in other branches of manufacture, the best and

most expensive thing is the cheapest in the end; yet it is an undoubted advantage that manufacturers have been able to lower their prices so much as to bring some kind of electric instrument within the reach of the humblest of our professional brethren.

I have already alluded to the circumstance that Gramme's principle of magneto-faradism (p. 87) may, in course of time, cause this agent to be again adopted for therapeutical purposes.

Doses of electricity require to be exactly measured to suit the different constitution, age, and sex of the patient, just as remedies for internal use are given by weight and measure; therefore every induction machine should possess a regulator by means of which the power of the current may be increased or diminished. The apparatus should be able to furnish a current of high tension, as otherwise no effect would be produced in cases of anæsthesia and hysterical paralysis, more especially when the electricity is applied to spots where the epidermis is very thick, such as the palms of the hands and the soles of the feet; on the other hand, a gentle current is required for persons of keen sensibility, and when acting on the face and neck.

We have seen in the first chapter that the intensity of the farado-magnetic current depends upon three conditions: viz. the intensity of the inducing current of the battery; the transverse section and the number of convolutions of the wires; and the quantity and the more or less insulated state of the soft iron in the centre of the coil. Consequently a current will be powerful if the battery be strongly charged, if the wire be long and fine, and the soft iron employed consist of a bundle of wires covered with a layer of varnish. It would be very inconvenient if we were obliged to vary all three conditions whenever it is necessary to diminish the intensity of the current. Before the researches of Prof.

Dove on the influence of a closed brass or copper tube on the power of the electro-magnet were generally known, it was customary to partially withdraw the soft iron from the axis of the coil, whereby the intensity of the current was diminished in proportion as the iron was withdrawn ; or to have portions of the iron connected severally with metallic knobs outside, on which a hand-plate or clock in connection with one of the poles was placed, so as to branch off either a feeble or a powerful current.

It is, however, as a rule, more convenient to use the brass or copper tube, or Du Bois' sledge arrangement (p. 128), as regulators, as they allow of a much nicer graduation than any other arrangement. For cases in which an extremely feeble current is required it is advisable to interpose an imperfect conductor into the circuit, whereby the resistance to the passage of the current is increased, and the strength of the current further reduced. This is done by a glass tube, the ends of which are furnished with metal screws for receiving the conducting wires of the apparatus. A metal rod is freely movable in the tube, which is filled with water as a bad conductor. The more the rod be taken out of the tube—i.e. the larger the layer of water which has to be traversed by the current—the more the power of the electricity is diminished, so that at last it will no longer be felt on the skin, but only occasion a slight pricking sensation when applied to the tongue or other mucous membranes. The same instrument may serve for comparing the intensity of different induction machines ; since, if the layer of water remains the same, the current furnished by a weak instrument will not cause any sensation in the tongue, while the current of a powerful one will be at once perceptible in that organ.

Some induction machines are too strong for therapeutical purposes. One of these is Rhumkorff's large coil, in which

the second wire is three miles long, whereby the current acquires a very high tension. The largest coil, which has been constructed is Apps's instrument, as exhibited at the Polytechnic Institution, which is nine feet ten inches long, and two feet in diameter. The length of the primary wire is 3,770 yards, and that of the secondary wire 150 miles. The soft iron in the centre of the coil is five feet long, four inches in diameter, and weighs 125 pounds. The action of this monster coil is excited by 48 cells of Bunsen's battery, each charged with a pint of nitric acid. The coil yields a flash of light 29 inches long, and capable of perforating five inches of solid plate-glass. It has been used by Dr. Richardson for physiological researches; but it would be totally unsuitable for therapeutical application.

The intensity of the *magneto-faradic* current depends upon the power of the fixed horse-shoe magnet, the number of convolutions of the wires, the distance of the soft iron armature from the poles of the magnet, and the velocity with which the wheel is turned. The most powerful magneto-electric apparatus which has been constructed is that of Mr. Henley. In this machine there are two permanent magnets, each of which is composed of thirty horse-shoe steel magnets two feet and a half long and from four to five inches broad; the induction coils attached to them contain about six miles of wire. The tension of the current circulating in this wire is far too high for medical use.

Most induction machines used in medicine furnish two currents, viz. the *primary or extra-current of the thick wire, and the secondary current of the fine wire.* Duchenne has expressed the opinion that there is a difference in the physiological action of the primary and secondary current, the former of which acts, according to him, chiefly on the contractile power of the muscles, while the latter has more effect on the sentient nerves and on the retina, when applied

by moistened conductors to any point of the face or scalp. Duchenne has referred this difference of action to a special elective power in each of the currents, which is equivalent to a confession of inability to explain the phenomena observed; while Becquerel [1] has contended that the difference in the physiological effects of the two currents is chiefly due to the difference which exists in their tension. Duchenne's observations are, according to Becquerel, accurate, but his explanations are unsatisfactory, as much difference naturally arises from the physical condition of the wires; a current circulating in a short and thick wire possesses less tension than one passing through a long and fine wire. The primary current has therefore only a trifling effect on the skin, which offers great resistance to the passage of electricity; and more effect on the contractile power of the muscles, which are better conductors of it; while the secondary current, which possesses a high tension, does not only affect the muscles, but also the skin and retina. For the same reason a layer of water is more easily traversed by the secondary than by the primary current. Messrs. Breton Frères have shown by an experiment, in which the arrangement of the wires was modified, that the effect which has been attributed by Duchenne to the secondary current, may be obtained from the primary, and *vice versâ*.

Rosenthal [2] has given the following most scientific explanation of the phenomena observed by Duchenne, which he considers as entirely owing to the peculiar construction of Duchenne's apparatus. The secondary coil of that instrument consists of extremely numerous convolutions of an exceedingly fine wire. Now, the electromotive force increases with the number of convolutions, but the resistance likewise increases with the length and fineness of the wire. There

[1] Traité des applications de l'Électricité, etc. Paris, 1857.
[2] Electricitätslehre für Medicin. Berlin, 1869, p. 194.

is, therefore, considerable resistance in Duchenne's apparatus. If the secondary coil be used for stimulating the sentient nerves, that resistance does not exert so much influence, as the dry cuticle has a still higher resistance ; and a considerable effect is therefore produced under any circumstances. The resistance of the coil is, however, of considerable influence upon the intensity of the current if we proceed to faradise the muscles. In the latter case the resistance of the body is considerably diminished by using moistened electrodes, while the resistance of the coil remains so great that the current cannot acquire any considerable degree of power. The very large number of convolutions of the secondary wire, therefore, rather constitutes a drawback when compared to the trifling advantage gained by increasing the inductive effects. If, however, the extra-current be used for faradising the muscles, a powerful effect is caused, inasmuch as the re-resistance of the coil is small, and that of the body is diminished, and the current is therefore sufficiently strong, even if the inductive effects are not very considerable.

Cyon [1] has lately given precisely the same explanation of these phenomena as Rosenthal did four years earlier, but without giving the credit of the argument to the latter physiologist. On the contrary, he says that even the latest writers on medical electricity regard Duchenne's theory as a 'sacred truth.' Such an assertion is, to say the least, singular, as almost all writers on this subject had, previously to adopting Rosenthal's explanation, sided with Becquerel rather than with Duchenne.

An important point in the construction of an induction apparatus is the *rheotome*, *cut-current*, or *contact-breaker*, by which the circuit is successively opened and closed, and which is indispensable, as induction currents only exist on

[1] Loc. cit. p. 172.

making and breaking the circuit, but not while it remains closed. The rheotomes used by electricians are the toothed wheel, the mercury rheotome, and the hammer.

a. *Toothed Wheel.*—The axis of a toothed wheel is connected with one pole of the battery, while the other is placed in contact with an elastic plate, which rests against the teeth of the wheel. A rotatory movement is then imparted to the wheel by means of a handle, whereupon the elastic plate leaps from one tooth to another, and each leap produces a rupture of the circuit, which is immediately closed again; so that, if the motion of the wheel be continued, a succession of interrupted currents takes place, which is slow or rapid according to the velocity with which the handle is turned. This instrument is ingenious, but not self-acting, which is a great drawback.

b. *The Mercury Rheotome* consists of two insulated vessels filled with mercury, two needles, and a metal rod. The needles are parallel with each other, and fixed transversely to the rod, which can be moved more or less rapidly by the hand or by clock-work. The circuit is closed when the needles are immersed in the two vessels, and opened if the contact between the needles and the mercury is broken. At the moment the needles emerge from the mercury, a spark is produced, by which the mercury is oxidised; its surface is therefore soon covered with a black powder of suboxide of mercury, which prevents a perfect contact between the needles and the metal. A rheotome which is rapidly spoilt by the action of the current is devoid of practical importance.

c. *The Hammer*, which was invented by Dr. Neef, of Frankfort, and made more generally known by M. de la Rive, to whom its invention is sometimes attributed, is the best of all rheotomes hitherto constructed, as it is self-acting and nearly indestructible, allows of rapid or slow interruptions, and notably increases the physiological effects of the

current. It consists of a small stem of soft iron (D E) placed beneath or above the induction coil (B); one end of this stem is fixed to a piece of metal (n'') outside the coil, while the other end, which is movable (E), is put in motion by the temporary magnetism of the soft iron (C) in the centre of the coil. A platinum spring is soldered to the lower surface of the hammer, and rests upon a piece of copper, likewise covered with platinum. The metal stem communicates with one of the poles (n) of the battery (A), and the piece of

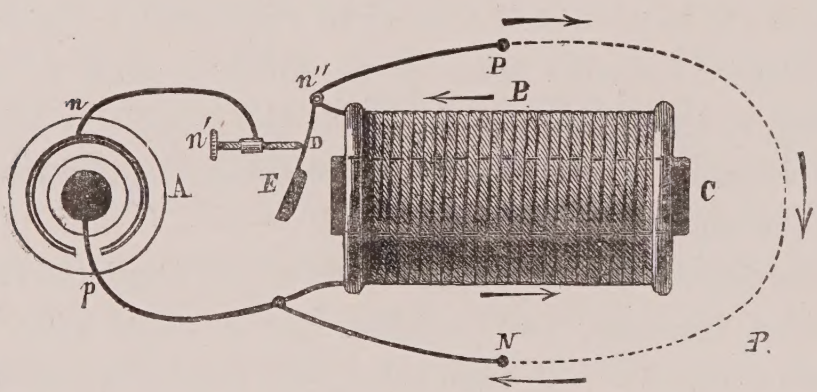

FIG. 108.—Neef's Hammer.

copper covered with platinum with the other pole (P). The circuit is closed each time that these come in contact with each other; as thereby the soft iron in the centre of the coil becomes magnetic, and therefore attracts the movable end of the hammer. In consequence of this the circuit is broken, since the contact between the two parts has ceased. The central soft iron then loses its magnetism, and the hammer drops by its own weight into its previous position. The circuit is thus closed, whereupon the soft iron regains its magnetism; the hammer is then once more attracted to the electro-magnet, and the circuit again broken. At each interruption a spark passes between the two pieces of platinum, which causes this metal to be slowly oxidised. The surface of the platinum therefore requires to be occa-

sionally cleaned; but a well-constructed hammer may, to all intents and purposes, be said to last a life-time.

The physiological effects of induction currents differ considerably, according to the rapidity with which they succeed each other. A rapidly-interrupted current has a more stimulating effect on the nutrition of paralysed muscles and on the sentient nerves of the skin, than one that is slowly-interrupted; but in certain cases, for instance, where there are symptoms of irritation, and likewise in delicate persons, it is too stimulating, and every good induction apparatus should therefore be furnished with a contrivance for changing the rate of succession of the currents. This is generally accomplished by working a screw (n' Fig. 108), which withdraws the spring of platinum soldered to the hammer from the piece of copper covered with platinum. If the distance between the two be small, the currents succeed each other rapidly; if it be increased, their rate of succession is retarded. The differences in the slow or rapid succession of induction currents are readily distinguished by the different musical sounds produced by the play of the hammer.

Fig. 109 shows a somewhat different arrangement of the same contrivance. a and b are coils of copper wire, in the centre of which a soft iron (c) is placed. + is the clamp for the positive wire of the battery, — the one for the negative. k is the stem of soft iron fixed to one end of a lever (e), and placed above the soft iron of the coil. f is the platinum point towards which the lever moves, and by means of which the current proceeds to the brass rod d, from where it returns to the battery. h is the spring by means of which the lever e is brought in contact with the platinum point, while i represents a screw which regulates the tension of the spring.

Several other contrivances have been proposed for effecting a continued interruption of the faradic current, such as

Maelzel's métronome, which is used by musicians, &c.; but the hammer is superior to any other arrangement, and has therefore been universally adopted by instrument makers.

I now proceed to describe very shortly some induction machines which are at present or were formerly commonly used in medical practice.

a. *Volta-faradic Machines.—Neef and Wagner's instrument* (Fig. 110) is of historical interest, as it was the first of

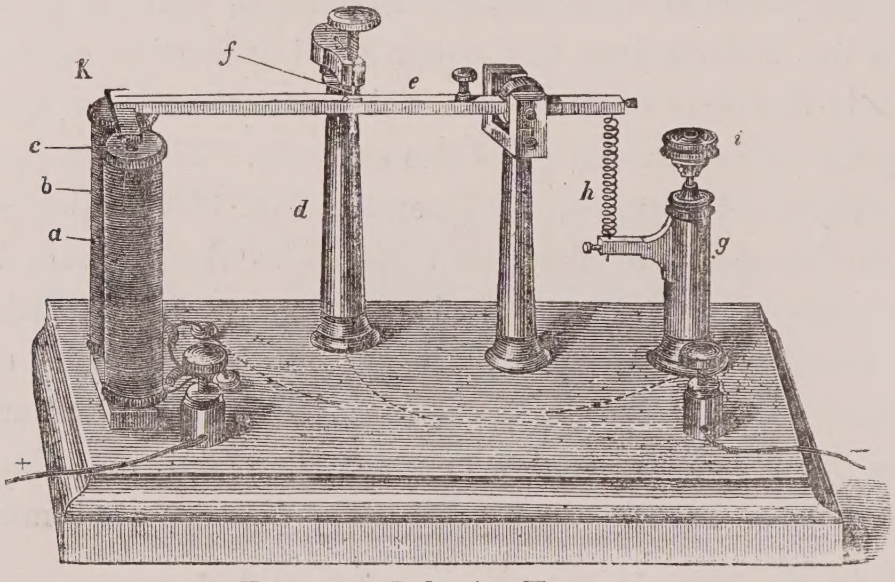

FIG. 109.—Induction Hammer.

this kind which was used in medicine. *a* + is the positive, *g* the negative wire, *b* and *d* are cups filled with mercury for the entrance of the wires. *f* is the commencement, *e* the end of the coil. *c* is the hammer, and *m* a copper wire which connects the hammer with the cup *d*. On connecting the battery with the coil, a musical sound indicates that the machine is acting.

Siemens and Halske's instrument (Fig. 111) is a modification of Du Bois' apparatus (p. 128). A A′ are clamps for receiving the conducting wires of the battery, and connected with the primary wire of the coil. E is the hammer fixed to the pillar *a*; *v* is the screw for making the current. C is the bundle of soft iron wire, contained in the cylinder;

B, D the soft iron wire in the form of a horseshoe, as in Du Bois' apparatus. B′ is the coil of fine wire furnishing the secondary current.

Benedict's apparatus (Fig. 112) is likewise a modifica-

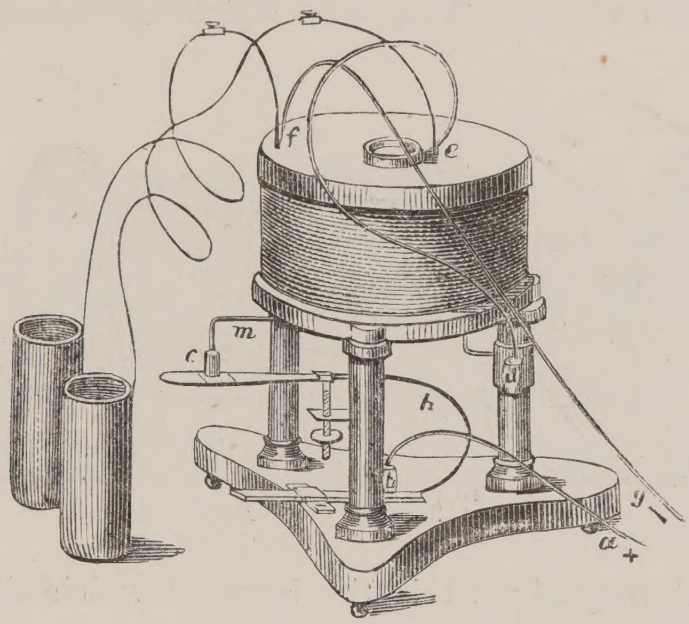

FIG. 110.—Neef and Wagner's Apparatus.

tion of Du Bois'. The battery current enters at *a b*; I is the coil of thick wire, II the coil of fine wire; *c d* yield the primary, *e f* the secondary current.

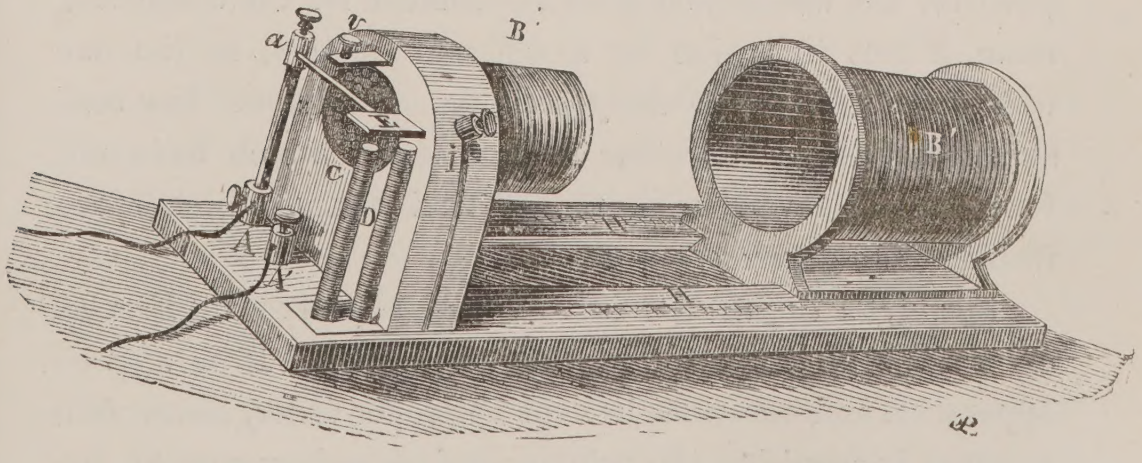

FIG. 111.—Siemens and Halske's Apparatus.

Duchenne's volta-faradic apparatus (Fig. 113) is put in action by a pair of Bunsen's battery, which is contained in

the lower drawer of the wooden box represented in the annexed diagram. A and B are copper plates, connecting the positive and negative poles of the battery, by means of the platinum pieces C D, with the coil of thick wire. K is a toothed wheel, by means of which the current may be

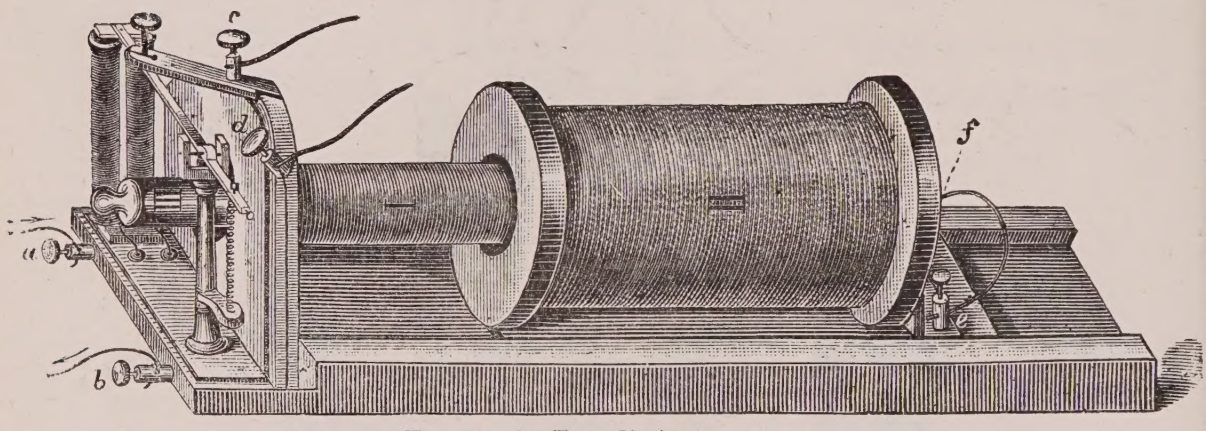

FIG. 112.—Benedict's Apparatus.

slowly interrupted; H I is the hammer which allows rapid intermittences. E F yield the secondary current. The brass tube (L) regulates the strength of the current. G is a tube of glass filled with water, by which a further diminution of the power of the current may be effected. Duchenne's apparatus is too large and heavy for out-door practice, but would be a good instrument for the consulting room, if put in action by a different battery, as the one used for it requires daily nursing. Duchenne has constructed a variety of other machines, but which have not found much favour with the profession, and which space forbids us to describe.

Legendre's apparatus is very generally used in France, on account of its portability and cheapness. It is a good apparatus, and one that, if kept in proper order, never fails to act. It furnishes the primary and secondary current, has a brass tube for regulating the power of the current, and a screw arrangement for rendering the intermittences rapid or slow. The chief drawback to the instrument is the

battery, which must be daily charged with nitric acid, whereby the apparatus is easily spoilt, unless great care be taken with it.

Gaiffe's bi-sulphate of mercury apparatus (Fig. 114) would be perfect for out-door practice, if the battery (L),

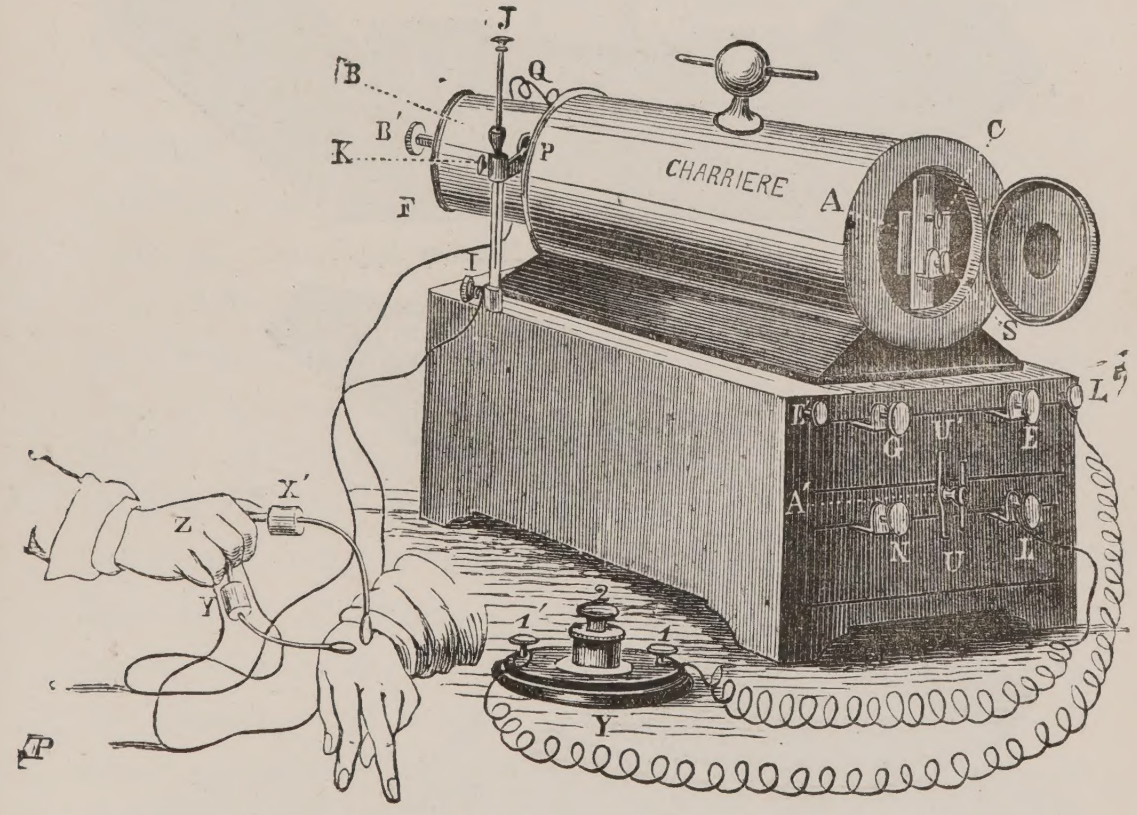

FIG. 113.—Duchenne's Apparatus.

were not somewhat uncertain in its action. It has the form of a book in post 8vo., and may be carried in the pocket. The necessary electrodes N T are contained in the box. M is the coil, Q the hammer, O its screw, and K a tube containing a provision of the bi-sulphate.

M. Gaiffe has recently constructed an apparatus which is put in action by a chloride of silver battery (Fig. 115). A B C D are the four corners of the case in which the apparatus is contained, and which has the form of a book in post 8vo. The box is divided in two partitions by the plate E F; one of them contains the battery, and the other the coil. U prevents the

lid from being closed before the hammer P is in its proper position. When the hammer is at P, it gives rapid intermittences; when at P′, the circuit is broken, but the hammer

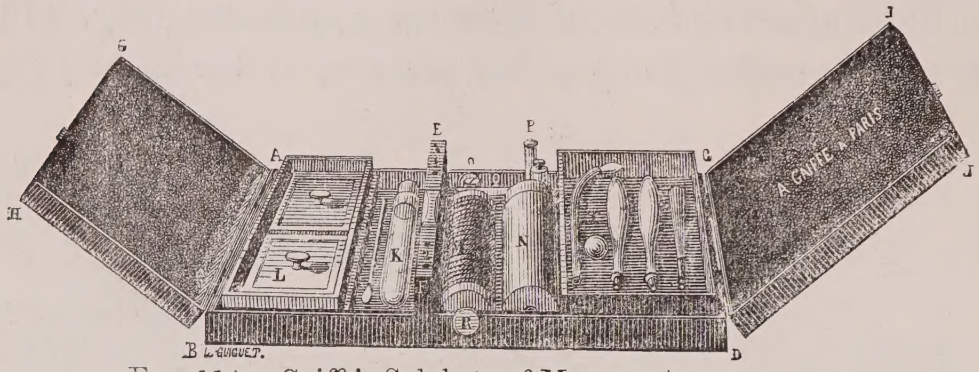

FIG. 114.—Gaiffe's Sulphate of Mercury Apparatus.

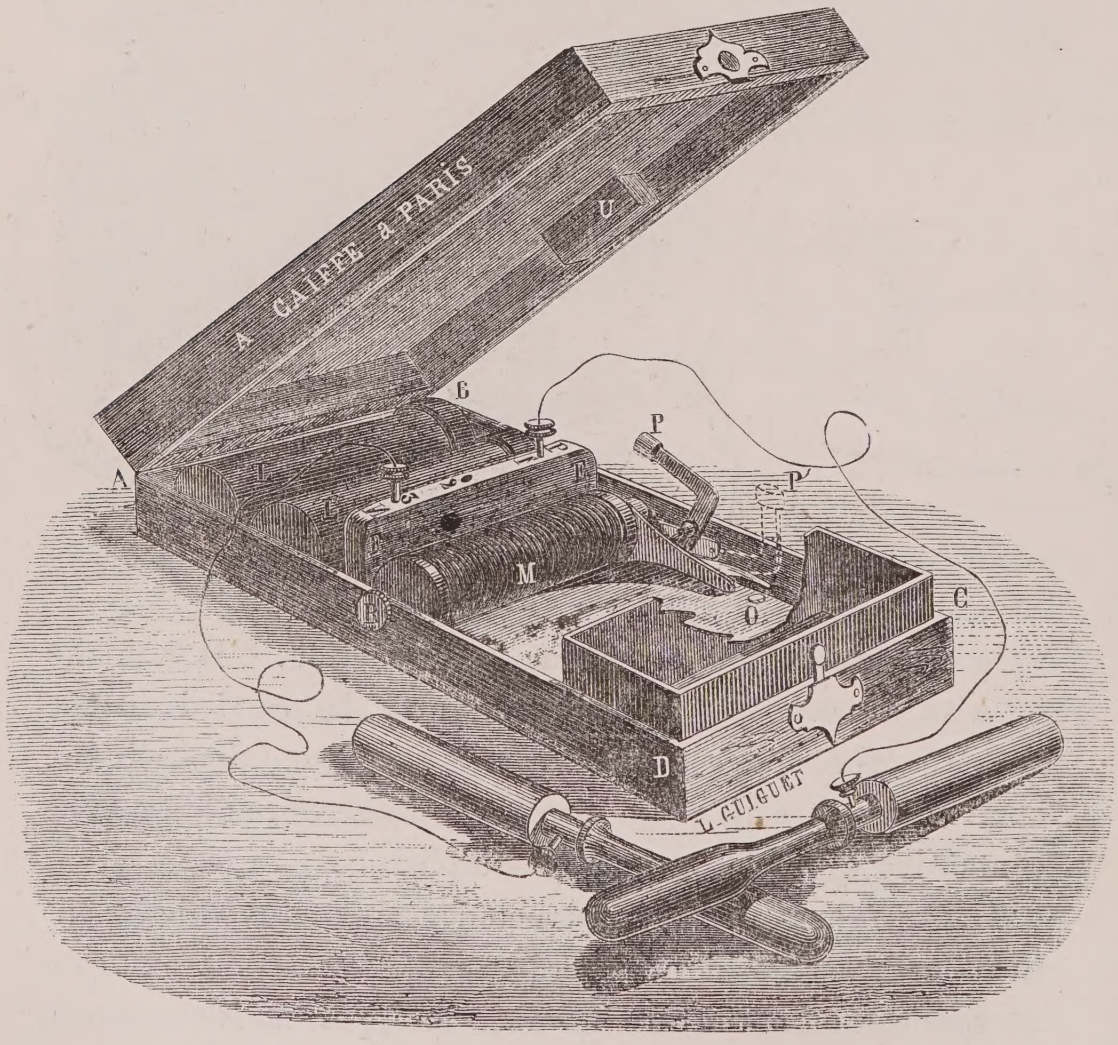

FIG. 115.—Gaiffe's Chloride of Silver Apparatus.

may still give very slow intermittences if pressed with the finger so as to connect it momentarily with the screw o. If

it be between P and P′, a medium rapidity is obtained. M is the coil of primary and secondary wire. E F is a plate from where the electricity may be collected; 1 and 2 give the primary, 2 and 3 the secondary current, 1 and 3 both currents united. P and N on this plate are the positive and negative poles. L L′ are the two pairs of the chloride of silver battery.

The most popular, and, on the whole, the best volta-faradic machine, is Stöhrer's, which has the great advantage that it is always ready to act, as the battery does not require daily nursing.

a. *Stöhrer's single-celled induction machine* (Fig. 115) is put in action by a pair of zinc and carbon charged with chromic and sulphuric acid. There is no porous vase. The interior of the carbon cylinder contains sand and 10 to 12 minims of a concentrated solution of chromic acid mixed with a sufficiency of water; it is closed by a glass stopper. The carbon cylinder is surrounded by a zinc cylinder contained in a glass, which receives diluted sulphuric acid in the proportion of 1 to 6. Both zinc and carbon are, by means of clamps, connected with the coil. The glass is placed on a small saucer of porcelain, which is connected with a metal rod, by means of which it may be raised more or less, so as to bring the different parts of the battery into contact with each other. When freshly charged it is best to raise the glass only just so far as to induce an effect, but not to the utmost limit; this having the advantage of keeping a portion of the zinc free from the action of the sulphuric acid. There is no fear of spilling the liquid if the machine be carried about, because it fills up only the lower third of the battery.

The zinc and carbon are connected by means of clamps with the primary coil and the contact-breaker. Both coils are contained in the interior of the case, and the secondary may be drawn over the primary by pulling up a graduated

rod. The hammer consists of an oblong piece of iron fixed to a spring, but so as to allow easy motion in two opposite directions. As soon as the battery current traverses the coil, the soft iron wire of the coil is rendered magnetic, and attracts the hammer. When the parts are in this position, the conduction is interrupted, as a platinum-pointed screw on the other side, which is connected with the coil, becomes separated from the hammer. The magnetism of the electro-

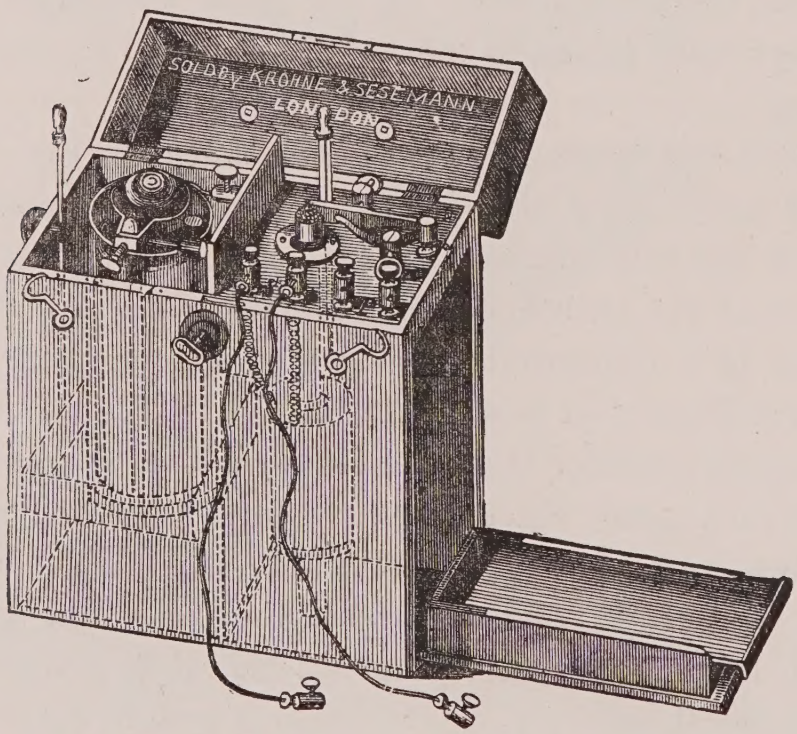

FIG. 116.—Stöhrer's Single-celled Induction Apparatus.

magnet is therefore lost, and the latter no longer attracts the hammer; the consequence is that this again touches the platinum-pointed screw, and re-establishes the communication between the battery-current and the coil. Fresh magnetism and fresh attraction are the result, followed again by cessation of conduction and magnetism. This play of the hammer repeats itself at regular intervals. The rate of succession of these instantaneous currents is regulated by a brass spring on the other side of the hammer, which is furnished with a screw, by means of which the hammer may

be pressed more or less forcibly against the platinum-pointed screw on the opposite side. If the brass spring be forced, the play of the hammer is retarded; if the spring be relaxed, the hammer beats more rapidly; and if the spring be entirely screwed off, the intermittences are most rapid. The pitch of the musical sound, and the intensity of the physiological action, correspond to these changes in direct proportion.

Stöhrer's hammer is so well made that the instrument may be used a long time before any oxidation of the platinum by the electric spark is caused. A certain degree of oxidation would interrupt the play of the hammer, and it may therefore be occasionally necessary to remove the oxide with the point of a pen-knife. There is, however, another ingenious contrivance connected with the hammer, in order to prevent the effects of oxidation. This consists of a small piece of brass, coated with platinum, and soldered to that portion of the soft iron which is opposite to the platinum-pointed screw. This brass piece is pierced in the centre, so that a pin on a metal rod may be inserted into it, and give it a turn, so as to bring a different portion of the disc in contact with the platinum-pointed screw, whereby a permanency of these parts is to a great extent ensured.

There are four studs for receiving the conducting wires. The two on the left side are marked P, and give the primary current, or that generated in the short and thick wire; and the two on the right side are marked S, giving the secondary current, or that generated in the long and fine wire. The graduation of the tension of both currents is effected: 1st, by the greater or lesser immersion of the battery plate into the exciting liquid; 2ndly, by altering the play of the hammer as described above; and finally by raising or depressing the stem connected with the outer coil of wires. The primary current may also be weakened by connecting the secondary studs with a piece of bent wire, and then

raising the external coil. An inner chamber contains the electrodes and conducting wires.

b. Stöhrer's *double-celled faradic machine* (Fig. 117) is much larger than the one-celled, and most carefully constructed. The battery is the same as in the smaller instrument, and can be used either by connecting the zinc of one with the carbon of the other cell, or by connecting the two

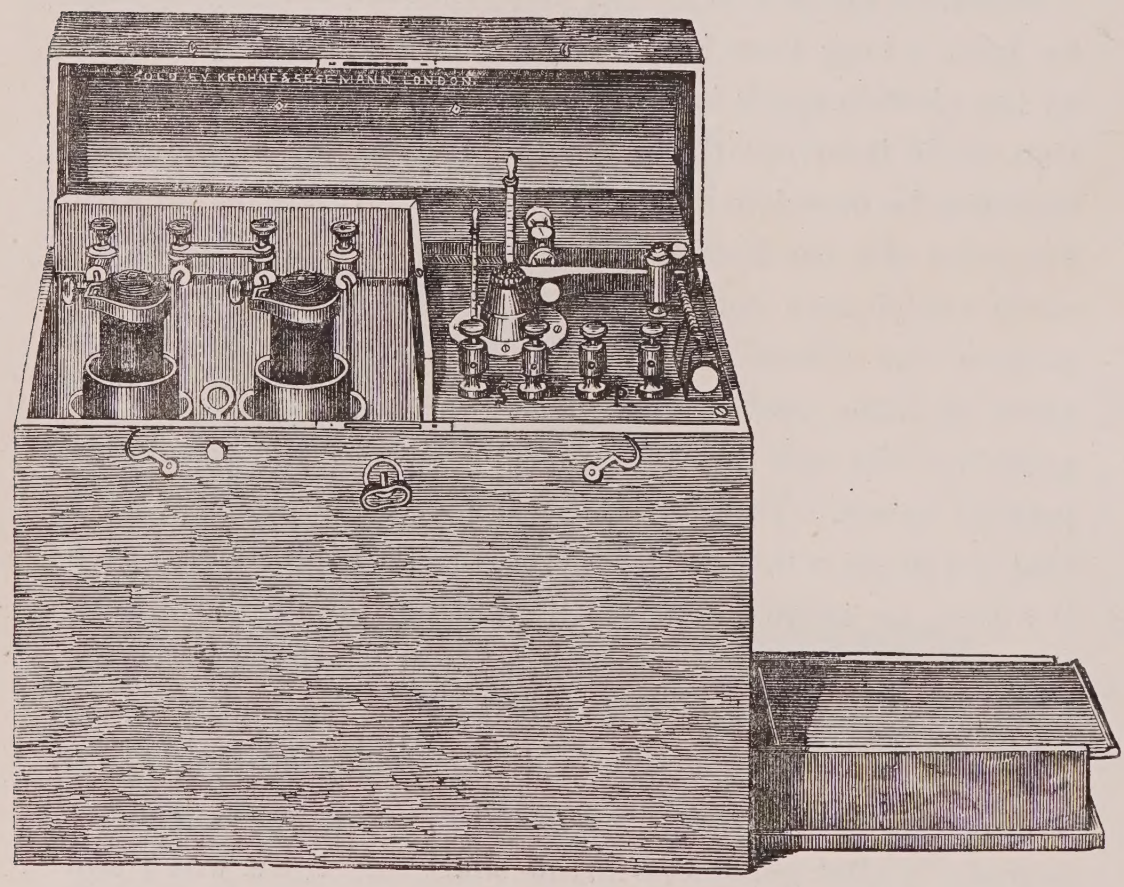

Fig. 117.—Stöhrer's Double-celled Induction Machine.

zincs and the two carbons amongst each other, so as to produce a single pair of large surface. The hammer is somewhat different, inasmuch as the platinum-pointed screw is situated in the hammer itself, while the platinum disc is movably fixed to a spring, the action of which is regulated by a screw behind. The play of the hammer may be modified by altering the position of either of the screws. The solidity and beauty of construction of these parts are beyond praise.

P and S are the same as in the smaller instruments. The graduation of the two currents is effected in the same manner; but for weakening the primary current, a further contrivance is added, which consists of a brass tube in the interior of the case, covering the primary coil. This tube may be drawn up or pushed down by a small graduated rod, which is seen to the left of the core of iron wire. It is used for faradisation of the face, the tongue, and other parts which possess an exquisite sensibility, and where a powerful current cannot be administered. The price of the one-celled induction machine is 4*l*. 4*s*., and that of the large, 6*l*. 10*s*. They may be procured in London from Messrs. Krohne and Sesemann, of Duke Street, Manchester Square, W.

Messrs. Krüger and Hirschmann, of Berlin, have constructed a nice portable induction apparatus, which is nursed by Leclanché's battery, and is likewise constantly ready for action. The play of the hammer commences as soon as a stopper is inserted into a brass block fitted for its reception. There is only one pair of studs for inserting the conducting wires; but by inserting stoppers in different ways, these studs will alternately give the primary and secondary current. The hammer is constructed in a somewhat different manner from Stöhrer's, but likewise allows slow and rapid intermittences. Both currents are easily graduated as far as intensity is concerned. The same manufacturers construct a smaller instrument nursed by one cell of Leclanché's. The price of the large apparatus is 3*l*. 15*s*., and that of the smaller 3*l*. Electrodes and conducting wires are contained in an inner chamber.

Messrs. Meyer and Meltzer manufacture an induction machine (Fig. 118) enclosed in a light mahogany box, 6 inches high, $3\frac{1}{2}$ inches deep, and 6 inches wide. The instrument therefore occupies only a small compass, and, nevertheless, gives all the different graduations of power which

may be required. The battery is one of zinc and carbon, nursed by a solution of bichromate of potash (2 oz.) and sulphuric acid (1 oz.) in 19 ozs. of water. The primary and secondary current may be used without changing the position of the conducting wires, which is a great convenience. The power of the current is increased or diminished by moving the

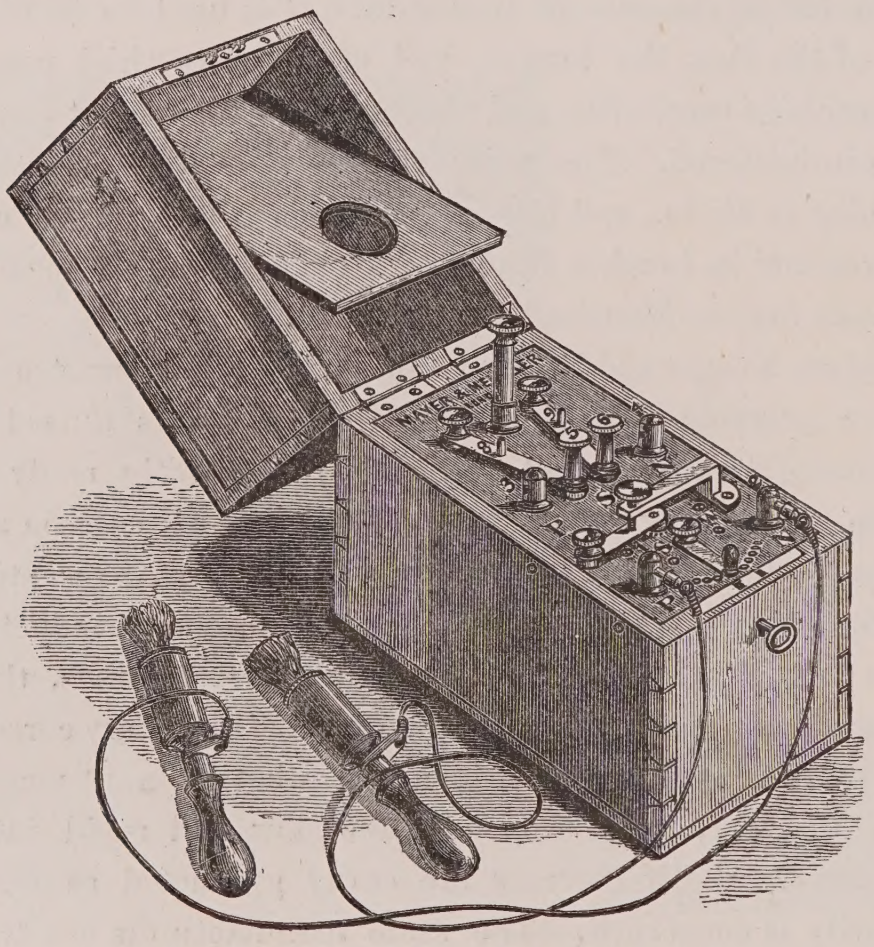

FIG. 118.—Meyer and Meltzer's Induction Apparatus.

dial either to the right or to the left side. The price is 4*l.* 4*s.*

Weiss's Faradic machine (Fig. 119) is, like everything which issues from that firm, well made. The battery is one of carbon and zinc (K), and is charged with a solution of bichromate of potash in diluted sulphuric acid. J is the handle by which it is pulled up when intended for use, and L the screw by which it is fixed in that position. The poles of the

battery N M are connected with those of the induction coil A B, whereupon the hammer *g* begins its musical performance. C

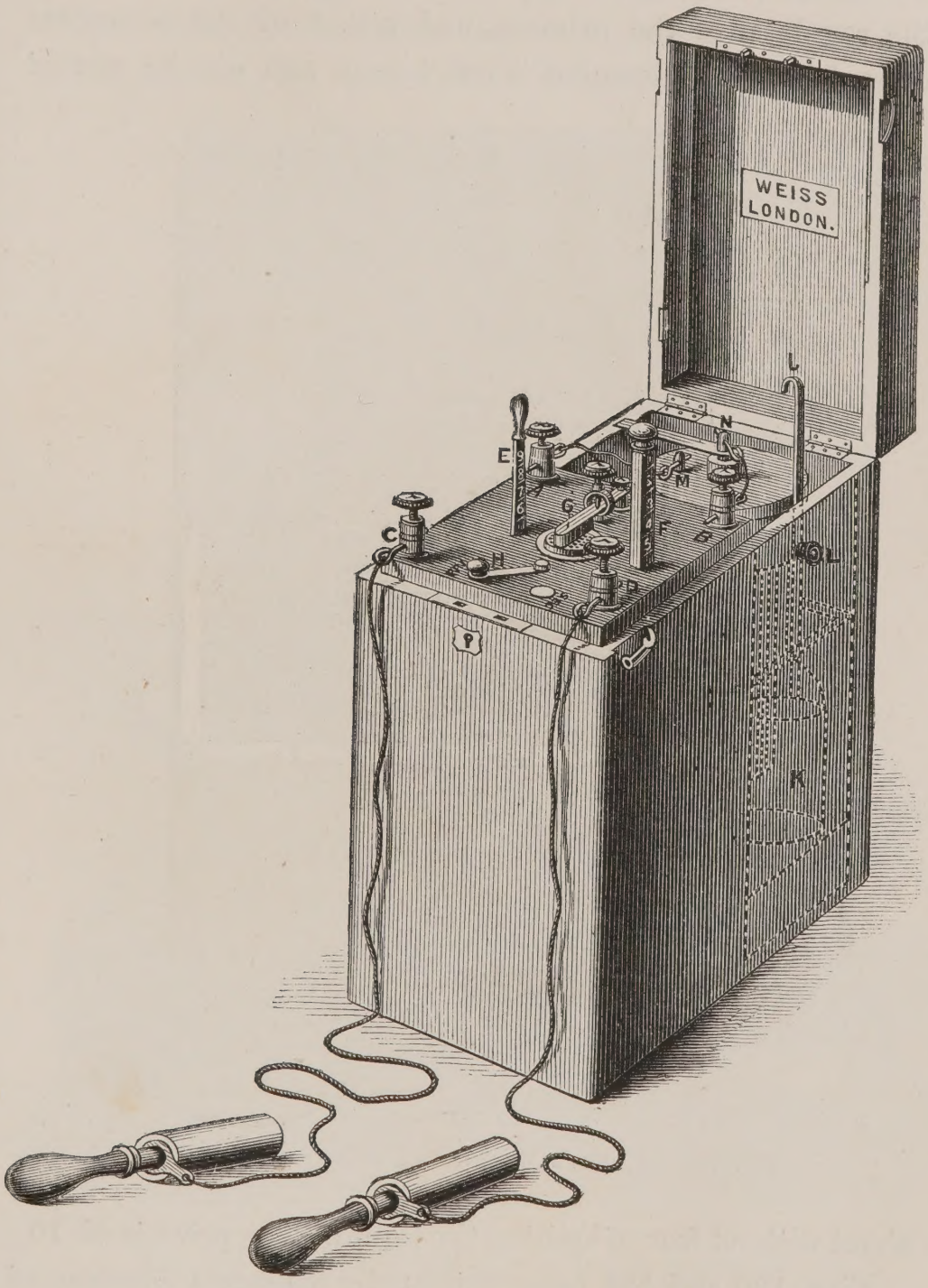

FIG. 119.—Weiss's Faradic Apparatus.

and D are the pole-studs of the induced current, and connected with the conducting wires, the other ends of which are

screwed on to the electrodes. If the primary current be required, the commutator H is turned on to *cri*, and if the secondary be wanted, the position is reversed to *sec.* E is the regulator of the primary, and F that of the secondary current. The instrument is not heavy, and can be carried

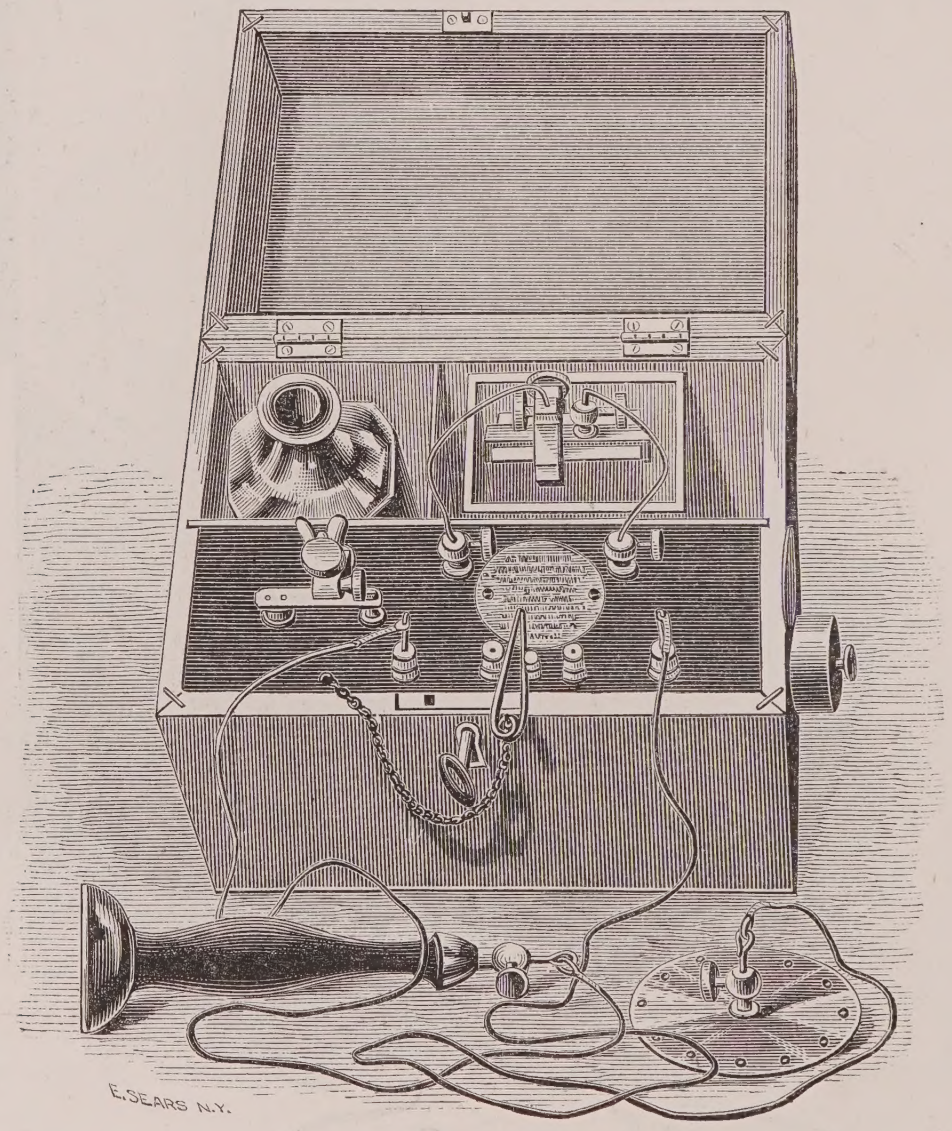

FIG. 120.—Kidder's Single-celled Induction Apparatus.

about without fear of spilling the liquid. The price is 4*l.* 10

Figs. 120 and 121 represent faradic machines constructed by Dr. Kidder, of New York; and Fig. 122 one made by the New York Galvano-Faradic Company; but which space does not allow us to describe in detail.

c. *Magneto-faradic machines* are quite unnecessary for those who can procure volta-faradic instruments, but may still be of advantage to practitioners in the colonies, &c., where it may be sometimes difficult to procure the exciting liquid necessary for volta-faradic machines.

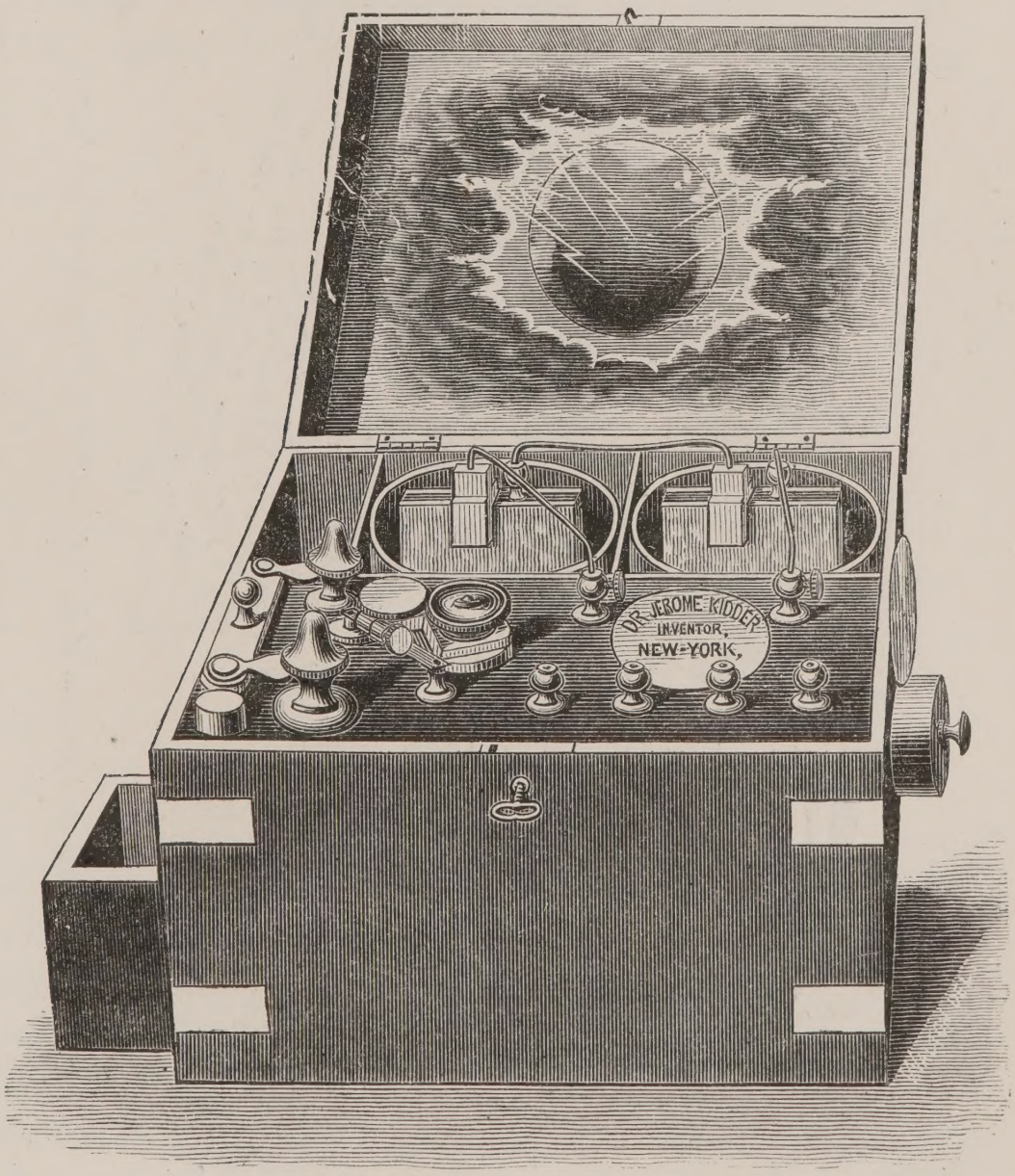

FIG. 121.—Kidder's Double-celled Induction Apparatus.

Pixiis' was the first rotation machine used in medicine. In this instrument the magnet was made to rotate, the soft iron being fixed. In all rotation machines, which have

subsequently been constructed, the reverse takes place. The instruments of Saxton, Ettinghausen, Keil, Dujardin, and Breton Frères are all out of use.

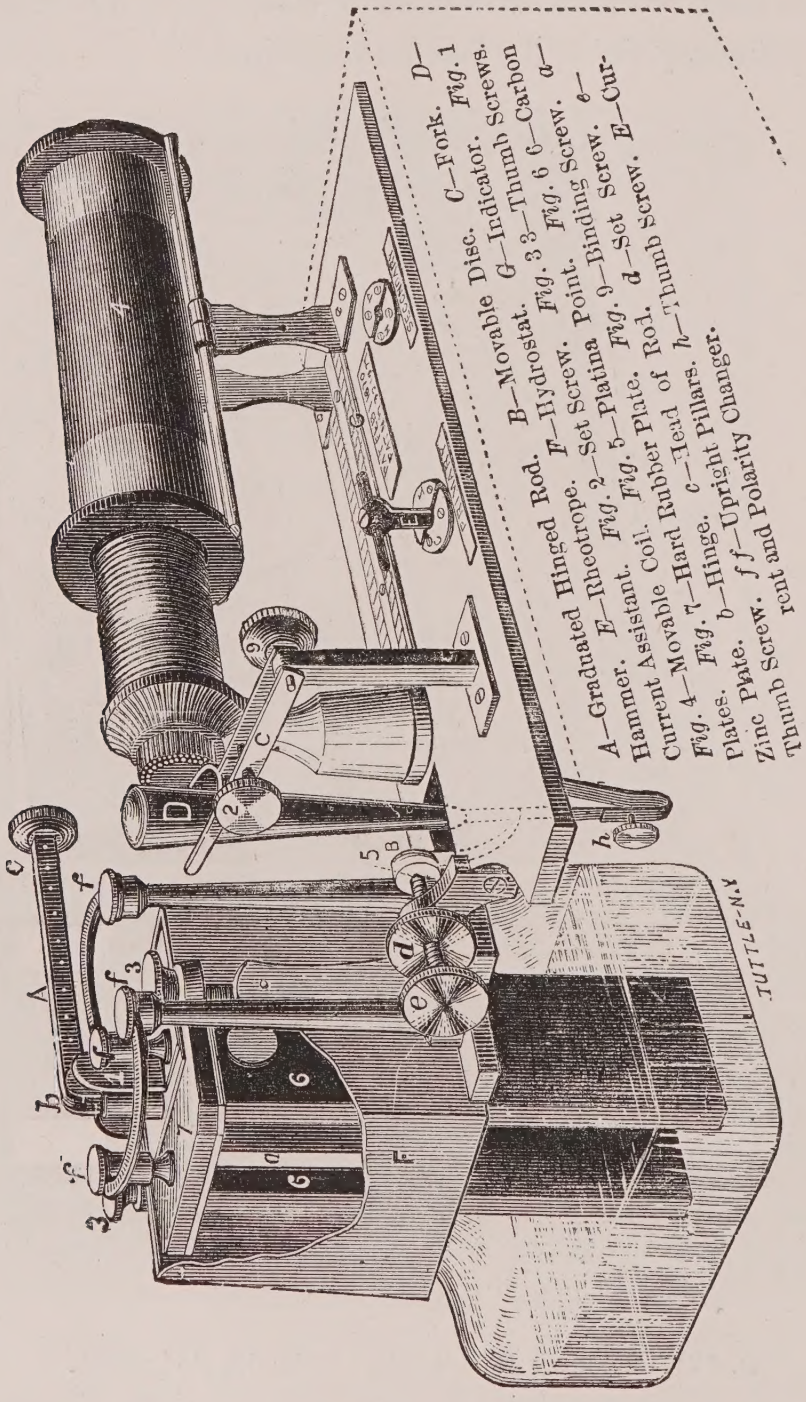
A—Graduated Hinged Rod. B—Movable Disc. C—Fork. D—
E—Rheotrope. F—Hydrostat. G—Indicator. Fig. 1
Hammer. Fig. 2—Set Screw. Point. Fig. 3 3—Thumb Screws.
Current Assistant. Fig. 5—Platina Plate. Fig. 6 6—Carbon
Fig. 4—Movable Coil. Fig. 9—Binding Screw. a—
Plates. b—Hinge. c—Hard Rubber Plate. d—Set Screw. E—Cur-
Zinc Plate. f f—Upright Pillars. h—Thumb Screw.
Thumb Screw. rent and Polarity Changer.
TUTTLE-N.Y.

Fig. 122.—Induction Apparatus of the Galvano-Faradic Company of New York.

Stöhrer's apparatus (Fig. 123) consists of a horizontally-placed horse-shoe magnet, composed of five pieces, and a soft iron armature, surrounded by coils of wires, a rheotome, and

an axis for turning the armature. 1, 2, 3, 4 are steel nozzles, connected with the wires of the armature, and so arranged that, by half a turn of the armature, 1 and 3 enter into action, while by the other half, 2 and 4, are touched. A toothed wheel serves for the interruption of the current.

Duchenne's magneto-electric machine (Fig. 124) is probably only used by its inventor. M is the handle, by means

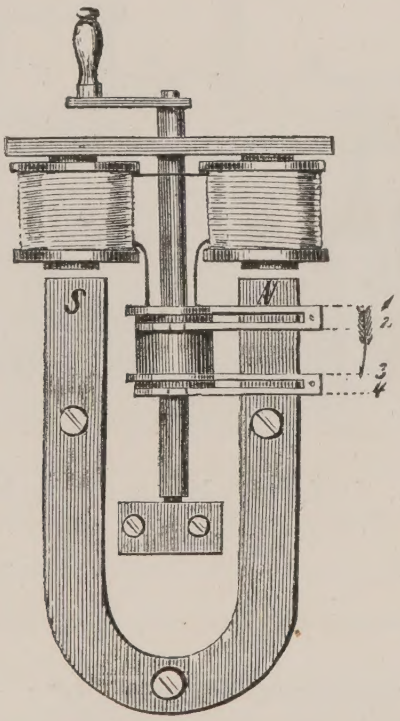

FIG. 123.—Stöhrer's Rotatory Apparatus.

of which the soft iron armature (G) is put in rotation. A is a wheel furnished with 64 teeth, so arranged that 32 intermittences of the current are produced by one revolution; and as the wheel may be turned twice in a second, 64 intermittences may be produced in that space of time. N is a screw by means of which the armature may be approached to, or withdrawn from, the magnet. H is the copper tube which regulates the intensity of the current, B S S, the rheotome. There is a coil of thick and fine wire (E), one end of which is connected with the knob P, for inserting one conducting wire, while the other end communicates with the support G,

which is connected with the second knob, P, by means of D, which regulates the intermittences of the current.

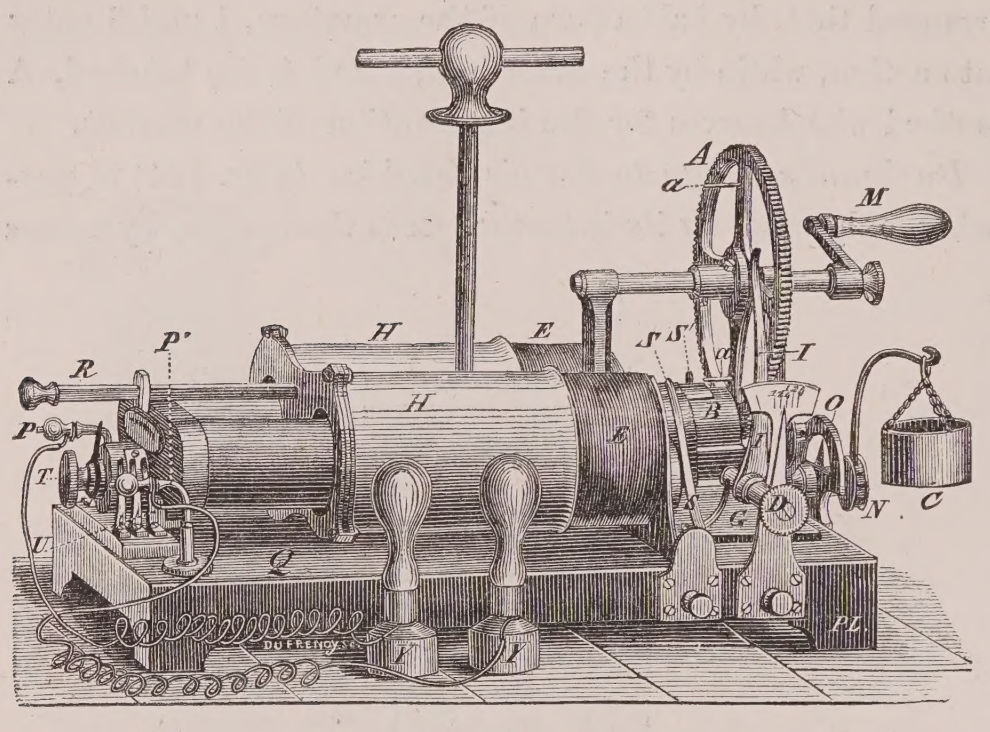

FIG. 124.—Duchenne's Magno-electric Machine.

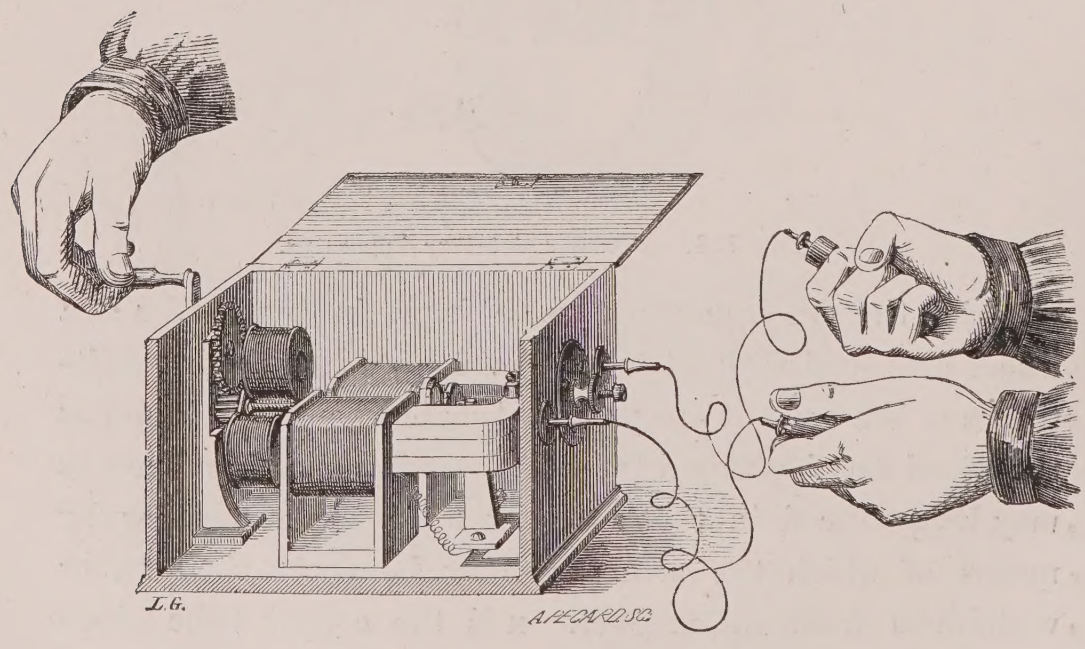

FIG. 125.—Gaiffe's Magno-electric Machine.

Gaiffe's magneto-electric machine (Fig. 125) is a more simple instrument. Both the permanent magnet and the

soft iron armature are surrounded by coils of copper wire, whereby the power of the current is considerably increased, without augmenting the bulk of the apparatus. The physiological effects of the current produced by demagnetisation being stronger than those of the current produced by magnetisation, only the former has been utilised, and the current of Gaiffe's machine therefore always moves in the same direction.

IV.—METHODS OF EMPLOYING VOLTA-FARADISM AND MAGNETO-FARADISM.

The method with which Duchenne's name is more particularly connected consists of the *localised* application of induction currents, while other physicians have recommended a more *general* application of the same over the whole body.

a. *General Faradisation* was first recommended by M. Dropsy,[1] of Cracow, but his proposal was supported by such singular reasoning as to provoke more ridicule than serious attention. He says that he has discovered a physiological formula for the distribution of electric sensibility throughout the body, according to which the top of the head is most sensitive, and a gradual decrease of sensibility takes place towards the feet. This formula is, according to Dropsy, altered in disease, and the object of the treatment is to change the pathological into the physiological formula. All that is necessary for accomplishing this is to put, by means of a bifurcated director, one pole of a magneto-faradic apparatus to the top of the head and the epigastrium, while a quadrifurcated electrode is made to connect the other pole of the machine with both hands and feet. By so doing, the pathological formula of all curable diseases is gradually

[1] Électrothérapie, ou application médicale pratique de l'Électricité, basée sur de nouveaux procédés. Paris, 1857.

changed into the physiological one, and *pari passu* the patient recovers. No diagnostic or methodological qualms need disturb the serenity of mind of an operator guided by Dropsy's law; but unfortunately, all curable diseases are not so easily eradicated as the Cracovian doctor would make us believe.

M. Seiler,[1] of Geneva, has recommended a method which savours strongly of mysticism. He condemns the direct application of electricity to the human body, and thinks it preferable to act from a distance. The operator holds two electrodes traversed by an induced current in his hands, and passes them gently through the air, at a certain distance from the patient's body. By this proceeding, which M. Seiler has called 'galvanisation by influence,' pain is said to be relieved, the muscles strengthened, and curvature of the spine, laryngitis, asthma, prolapsus uteri, consumption, and a host of other diseases cured. It is difficult to believe that the author has been serious in propounding such an absurdity.

A more sensible attempt to introduce general faradisation into medical practice was made by M. Gubler,[2] who proposed placing both hands and feet in four separate basins filled with salt water, and then sending the current through the body for fifteen minutes at a time. He has seen good results of this method in cases of general weakness, loss of appetite, impotency, &c.

Messrs. Beard and Rockwell,[3] of New York, carry out a somewhat different mode of general faradisation, which they believe to be especially suitable for cases where a general tonic effect is desired, as in dyspepsia, rheumatism, amenorrhœa, chorea, constipation, anæmia, and other diseases

[1] De la Galvanisation par influence. Paris, 1858.

[2] De l'Électrisation générale, considérée comme agent tonique et stimulant diffusible. Bulletin de Thérapeutique. December 1863.

[3] The Medical Use of Electricity, with special reference to General Electrisation. New York, 1867.

associated with deficient vital energy. They recommend the following *modus operandi* :—'Male patients remove their stockings and all their outer and under clothing from the upper part of the body and place their feet on a piece of copper, to which the negative pole is attached, while the operator uses the positive electrode, which is either a moistened sponge or his hand, thus making the current pass through his own person into the body of the patient. Ladies remove their dress and loosen their under garments, and throw over their shoulders a shawl or sheet. The most thorough form of application demands that the entire surface of the body should be gone over with some regard to order. Special pains should be taken to avoid the scapula, clavicula, sternum crest of the ilium and tibia, inasmuch as these and other bony prominences are very sensitive to the electric current.' Messrs. Beard and Rockwell are convinced 'that no instrument that human skill shall devise can ever equal the hand in flexibility and power of adaptation,' as the operator can, by increasing or diminishing his grasp of the sponge, modify the strength of the application without disturbing his apparatus. When used in this way the current must pass through the body of the operator. 'To this the system appears soon to become accustomed, just as it does to the use of tobacco, alcohol, opium, haschish, or coca; with this difference, however, that the effects of electricity are, if anything, positively beneficial.' Messrs. Beard and Rockwell mention that a person living in New York has during the past thirty-five years allowed the stream to pass through his own body on an average for about five hours each day, or about seven years of his life; that up to the present time the general health of the person alluded to has been excellent, and he has suffered from no disease that can even remotely be ascribed to electricity. They appear to have obtained good results from their method in cases of neuralgia, chorea,

amenorrhœa, rheumatism, and similar affections, and look upon general faradisation as a tonic and corrective of the greatest efficacy. There can be little doubt that by thus acting on, and modifying the condition of, the sentient nerves of the skin and of the motor nerves and muscles,

FIG. 126.—General Faradisation.

benefit may result from the American method in certain functional nervous affections; but it is equally clear that the *modus operandi* must be extremely tedious to both operator and patient. Generally speaking, such an application cannot take less than half an hour, and yet it cannot possibly,

in many instances, be as useful as the application of the continuous current for a few minutes. The choice, under these circumstances, cannot be doubtful. Moreover, the inconvenience to the operator by the American method must be considerable, as the fingers are extremely sensitive to faradic electricity. Yet I can conceive that the American method may be very useful in certain conditions of the nervous system.

b. *Localised Faradisation.*—This method was invented by M. Duchenne,[1] of Boulogne, who, being convinced that all previous methods of applying electricity were wrong, applied himself to solve the problem whether it was possible to localise electricity in the skin without acting on the organs beneath it, or to make it traverse the skin without irritating it, for acting on a nerve or muscle. The following facts are the basis of his system of localised faradisation:—

When the skin and the electrodes are dry, and the epidermis very thick, as it is in many persons whose business exposes them much to the air and hard work, the two currents proceeding from an induction apparatus meet on the surface of the epidermis without penetrating the skin. They produce sparks and a kind of crepitation, but no physiological effects. When dry conductors are placed on parts of the skin which are sensitive to electricity, the person subjected to the experiment perceives a sensation of pricking and heat, which varies according to the intensity of the current. But when the skin and the electrodes are moistened, neither sparks, crepitation, nor sensation of heat are caused; but other phenomena occur which show that the electricity acts on a muscle, nerve, or on the surface of a bone. In the last case, severe pain of a peculiar character is caused by the

[1] De l'Électrisation localisée et de son application à la physiologie, la pathologie et la thérapeutique. Paris, 1855; 2nd edition, Paris, 1861; 3rd edition, 1872.

current acting on the nerves of the periosteum; and it is therefore considered bad practice to place the moistened electrodes of an induction apparatus on the surface of a bone. When the directors are placed on the surface of a muscle the latter contracts, and a sensation is produced which is not peculiar to the skin, but always accompanies the electro-muscular contraction, and is owing to faradic excitation of the sentient nerves of the muscles. Finally, when the conductors are placed on the surface of a motor nerve, contractions of all the muscles animated by that nerve are produced.

Duchenne therefore proposed two different methods of faradising the muscles, viz. by localising the faradic stimulus in the nervous plexuses or branches, which communicate their excitation to the muscles animated by them ('indirect muscular faradisation'); and by directing the current to the muscular tissue itself ('direct muscular faradisation'). In both cases the skin and the electrodes should be moistened. For the muscles of the trunks and the limbs moistened sponges are used, which are placed in metallic cups fixed on insulating handles. For localising the electric force in the smaller muscles, such as those of the face or the interossei and lumbricals, small conical directors, which are likewise fixed on insulating handles, are used. These conductors should be covered with moistened chamois leather, pieces of glove, or sponge.

Duchenne found that when the faradic current was directed to particular points of the skin, muscular contractions were more easily produced than when the directors were applied to other parts. These points he called 'points of election;' but he did not state, nor indeed perceive, that they are the points of entrance of the motor nerves into the muscles. This was done by Remak,[1] who contended that the degree of con-

[1] Ueber methodische Electrisirung gelähmter Muskeln. Berlin, 1855.

traction of a muscle was exactly proportionate to the quantity of motor nerve-fibres embraced by the current at its point of application; and that there was no direct action upon the muscular tissue itself, which was thrown in commotion merely through excitation of the motor nerves. He, therefore, proposes to call Duchenne's indirect muscular faradisation 'extra-muscular stimulation,' and direct muscular faradisation 'intra-muscular stimulation.' This theory was more fully developed by Ziemssen,[1] who first clinically determined the precise localities of these points of election, and marked them upon the skin with nitrate of silver. He afterwards dissected the motor branches of the nerves in dead bodies, and marked their points of entrance into the muscles, when it was discovered that the results of the two series of experiments completely agreed with one another. A third series of observations was undertaken on bodies immediately after death, when the excitability of the nerves and muscles was still extant. The motor points were first determined by faradisation, then marked with nitrate of silver, and afterwards the test of dissection was applied, in order to see whether they really corresponded to the points of entrance of the motor nerves into the muscular substance.

From these observations Ziemssen concluded that, if the epidermis be moistened, and moistened electrodes are somewhat forcibly pressed against the skin, the induced current passes through the corium, panniculus, fasciæ, and layers of muscular substance, to the nerves, and rouses their special energy, without acting so much on the nerves of the skin as to cause reflex action or severe pain. The electricity, however, penetrates into such a depth only at those points where the negative and positive currents enter the body. Between these two points of entrance the current follows the liquids

[1] Die Elektricität in der Medicin. Berlin, 1857; 3rd edition, 1866; 4th edition, 1872.

contained in the tissues, and does not produce any stimulating effects unless it be very powerful; but even in the latter case the chief effects are manifested, not in the whole circuit enclosed between the two electrodes, but only in their more immediate neighbourhood.

The effects obtained by intra-muscular faradisation are more powerful with large than with small electrodes. If a moistened conductor with a small surface be placed on the pectoralis major, or deltoid muscles, only a few fasciculi of the muscles are seen to contract, even if the current be powerful; but if electrodes be used which have a diameter of an inch or more, the whole substance of the muscle is made to move, even if the current be not very powerful. Faradism applied by large electrodes has less effect on the sentient nerves, and consequently causes less pain, than if conveyed by a small conductor. This also holds good where a direct action on the motor nerves is produced; and it is therefore advisable, for both intra-muscular and extra-muscular faradisation, to use large electrodes in preference to small ones. The electrodes which I generally use have two inches in diameter. It is different if it be intended to faradise muscles with a very small surface, or fine nervous fibres, either for clinical demonstration or for the purpose of diagnosis. In such cases small directors must be used for obtaining a decisive result.

Remak and Ziemssen have both denied that there is an irritability proper of the muscular fibre, and therefore did not believe it possible to produce muscular contractions by direct faradic stimulation of the muscular tissue. The existence of Hallerian irritability has, however, now been amply proved (p. 225), and it has been shown that the faradic current may disturb the molecular equilibrium of the muscles just as well as that of the motor nerves. The latter however is more easily disturbed by the current than the

former, and it is therefore necessary for causing intra-muscular contractions to use a current of greater power than is required for producing contractions by faradisation of the motor nerves. In the majority of cases however the contraction produced by placing electrodes on the belly of the muscle is composed of two elements, viz. intra- and extra-muscular faradisation. For those who have had no opportunities of studying the application of faradism in hospital practice, preliminary experiments in their own persons are strongly to be recommended before they apply the current to private patients. This is more especially necessary when a new instrument is used, with which the practitioner is not yet familiar. Where the current is to be applied to the face or neck, its strength should be first examined on the face of the operator; but if the application is intended for any other part of the body, the back of the operator's hand is the best test. If the sensation produced is very unpleasant, the power of the current should be diminished, and if no sensation be produced, it should be increased. It should likewise be borne in mind that every body has his own special sensibility to all forms of electricity; and that it is wise to assume, in the commencement of the treatment, rather a high than a low degree of this sensibility in a given case. It is very easy to increase the intensity of the current, if an insufficient power has been used at first; but it would be often difficult to obliterate from the patient's memory the recollection of a severe shock received in the first instance.

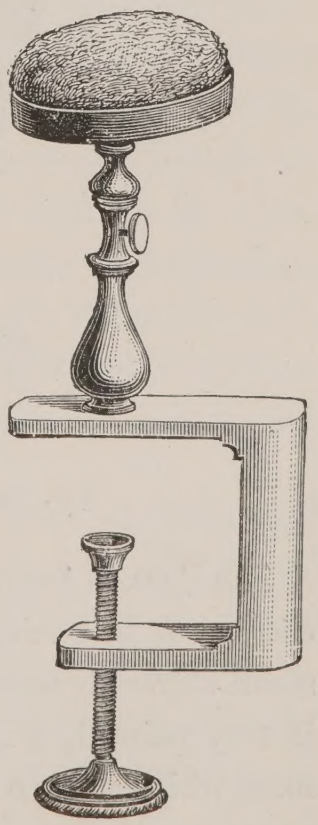

FIG. 127.—Fixed Sponge Electrode.

The following details of the method of faradic excitation of the motor nerves and muscles have been drawn up with special reference to the investigations of Duchenne[1] and Ziemssen.[2] It is only fair to say that the latter must be looked upon as the originator of the scientific method of faradising the motor nerves and muscles in the human subject.

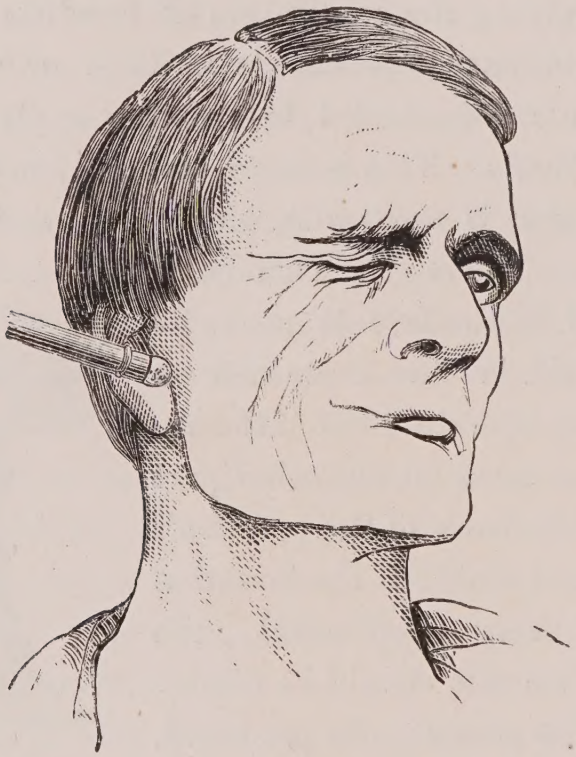

FIG. 128.—Faradisation of the Portio Dura.

The Face.—According to Duchenne, the *trunk of the portio dura* may be excited from the external meatus, by pressing a small electrode against its lower side; but as this proceeding is very painful, it is better to put the electrode into a small fossa which is seen in the concha of the ear, just below the porus acusticus externus; or to the nerve where it emerges from the stylomastoid foramen, below the concha, and be-

[1] Physiologie des Mouvements. Paris, 1867. Mécanisme de la Physiognomie humaine. Paris, 1862.

[2] Loc. cit. p. 237. The woodcuts in this section have been, by special permission, copied from Prof. v. Ziemssen's work.

tween the mastoid process and the condyloid process of the lower jaw. As soon as these points have been touched, there is a fearful grimace: the patient frowns on one side, closes his eye, and nose and mouth become displaced in a truly appalling manner.

Branches of the Portio Dura.—The ramus auricularis posterior, which animates the occipital muscle, the retrahentes auriculæ and the attollens, is found just behind where the cartilage of the ear is connected with the skull, at the anterior portion of the mastoid process. Faradisation of it causes the ear to be raised backwards and upwards, and the scalp to be drawn backwards.

The ramus auricularis posterior sub-divides into a posterior and anterior branch, either of which may be separately acted upon. Faradisation of the posterior branch moves the scalp, while stimulation of the anterior branch draws the ear in the directions just described. A small branch of the same nerve animates the tragicus and antitragicus muscles, and may be found on the mastoid process. Faradisation of it causes narrowing of the fissura intertragica, and wrinkling of the skin; the antitragus is approached to the tragus, and both are drawn upwards and inwards.

The branches of the portio dura which animate the stylohyoid and digastricus muscles may be separately faradised only in people who are very thin, by pressing a fine electrode behind the condyloid process of the lower jaw. Fat and a well-developed platysma myoides frequently impede the success of this experiment. If it answers, the hyoid bone is moved outwards, backwards and upwards.

The larger branches of the portio dura may be easily found on the parotid gland, but varieties are of not unfrequent occurrence. The branches for the Musc. *attrahentes auriculæ* and *attollens auriculæ*, may be faradised on the zygomatic process of the temporal bone, and when excited,

cause the concha to be raised upwards and forwards. The branch for the *frontal muscle* is found on the zygomatic arch and the temple. This muscle is also accessible to direct or intra-muscular faradisation, but its contraction is then not so thorough, nor so easily observed, as when its own special motor nerve is faradised. The forehead then shows a number of horizontal wrinkles, which vary in depth and intensity according to age, and also to the strength of the current. The glabella and the upper eyelids are at the same time displaced.

The branch for the *corrugator supercilii* is found in a line crossing the zygomatic arch in a direction from the external opening of the ear upwards to the brow. Its contraction depresses the brow, so that the eye becomes shaded in a direction from above and without. A maximum of contraction causes the brow to cover the upper eyelid. One portion of the muscle, at the same time, raises the inner portion of the brow upwards and inwards, and the skin of the forehead is vertically wrinkled.

The motor branch for the *orbicularis palpebrarum* may be faradised on the zygomatic bone, or beyond the same, on the parotid gland. Near the margin of the orbit this branch subdivides into an upper and a lower one, which go severally to the upper and lower portion of the muscle. When faradised before the division has taken place, this branch causes the eye to be completely closed, and the skin of the eyelids to be wrinkled.

The *zygomaticus major* muscle may be indirectly faradised by placing a fine electrode to the lower and external edge of the zygomatic bone; but its branch is very close to the branch of the orbicularis, so that they are often faradised together. As, however, the nerve is easily pressed against the zygomatic bone, its isolated faradisation offers no difficulties. The effect is, that the angle of the mouth and part of

the upper lip are drawn upwards and outwards, and the skin of the cheek is wrinkled.

The *zygomaticus minor muscle* is best faradised on the inferior edge of the zygomatic bone, just where it unites with the upper jaw-bone. The effect is, that the upper lip is drawn upwards and outwards; and as the ramifications of the supra-orbital nerve (from the fifth) are at the same time faradised, the proceeding is decidedly unpleasant.

The *levator labii superioris* is not very easily put into isolated faradic contraction, principally because the infra-orbital nerve is just behind it, and causes reflex movements by its faradic stimulation. It raises the upper lip nearly in a perpendicular direction, and the teeth become visible if its contraction is thorough.

The *levator labii superioris alæque nasi* may be faradised at a point corresponding to the lower end of the superior third of the side of the nose, and raises the upper lip and lateral cartilages of the nose.

The *compressor* and *pyramidalis nasi* may be faradised from a point only little above the one just described. The skin of the nose is thereby wrinkled; the skin of the glabella is smoothed by being pulled downwards; and the inner part of the eyebrow is drawn downwards and inwards.

The *orbicularis oris* muscle receives four branches of the portio dura, viz. one for each side of each lip, and requires therefore to be faradised by four electrodes simultaneously in order to be completely contracted. The branch for the *buccinator* muscle is found at the internal border of the masseter; but the muscle may also be faradised from the oral cavity: the mucous membrane is then strongly wrinkled, and the cheek pressed against the teeth.

The *triangularis menti* receives a branch which also spends motive power to the mentalis, while the *quadratus menti* must be faradised intra-muscularly. The *levator*

menti, on the other hand, receives a small branch from the portio dura which may be directly faradised. The *masseter* and *temporalis* must be directly faradised, on account of the deep situation of their nerves.

The Nerves and Muscles of the Neck.

The *subcutaneous colli* may be indirectly faradised by putting one electrode to the inner edge of the middle portion of the sterno-cleido-mastoid muscle, and the other to the middle of the ascending branch of the lower jaw; the former excites the nerves going to this muscle from the cervical plexus, and the latter the branches proceeding towards it from the portio dura. The external branch of the *accessory nerve* is found behind the sterno-cleido-mastoid muscle, where it proceeds to the trapezius. When this is faradised the cervical spine is flexed, the lower jaw pushed forwards, and the head so turned towards its axis that the face is turned towards the opposite side; at the same time the shoulder is raised, and approached to the mastoid process.

The *sterno-cleido-mastoid* may be faradised by putting the electrode a little below the points from where the accessory nerve is faradised. If both muscles are faradised, the face is drawn forwards, the chin raised, and the cervical spine strongly flexed. The *trapezius* is indirectly faradised by putting the electrodes to the terminal branch of the accessory nerve, which is very superficial. If both muscles are faradised, both shoulders are raised, and the shoulder-blades drawn towards the spine.

The *hypoglossus nerve* may be reached above the large cornu of the hyoid bone, before the hyoglossus muscle. A branch for the *omohyoid* muscle is found at the inner edge of the sterno-cleido-mastoid muscle, while the sterno-thyroid and thyro-hyoid must be directly faradised.

The *phrenic nerve*, which takes its rise from the third,

fourth, and fifth cervical pairs, proceeds downwards and inwards in front of the scalenus anticus muscle, before it reaches the mediastinum and the diaphragm. It is accessible to faradism on the anterior surface of the scalenus anticus. Moistened sponge conductors are pressed to the points just mentioned, when an artificial inspiration is produced; the thorax is expanded, and the air rushes with force into the lungs. By faradisation of the phrenic it is possible to maintain respiration for some time after death; and the proceeding has been successfully employed in cases of asphyxia where other means had already been used and failed.

The *posterior thoracic* nerve is found a little below the external accessory, and when faradised causes contraction of the rhomboid and serratus posticus superior muscles; the shoulder-blade is drawn towards the spine and upwards, and the upper ribs are gently raised. The *lateral thoracic* nerve, which animates the *serratus anticus*, is found closely above the collar-bone, and near the edge of the trapezius. If faradised, the shoulder-blade is pushed forwards and outwards, and the acromion is raised, so that the space between the spine and the shoulder-blade becomes nearly double that of the opposite side. The collar-bone is removed from the thorax, and the supra- and infra-clavicular fossa become hollowed.

The *anterior thoracic* nerve may be found either above and behind the collar-bone, or after having passed below it, at the upper border of the *pectoralis major* muscle. Faradisation of it causes the arm to be adducted to the chest, so that the elbow is placed to the mammillary line.

Nerves and Muscles of the Upper Extremities.

The *axillary* nerve, which animates the deltoid, may occasionally be directly faradised in the armpit, or where the nerve winds itself round the humerus. The *musculo-*

cutaneous nerve is found in the sulcus between the coraco-brachial and the biceps muscles. The fore-arm is, by its faradisation, powerfully flexed, in consequence of the contraction of the biceps and brachialis internus muscles. The *median* nerve may be reached on the inner and inferior third of the humerus, next to the brachial artery; its faradisation causes contractions of the pronator teres and quadratus,

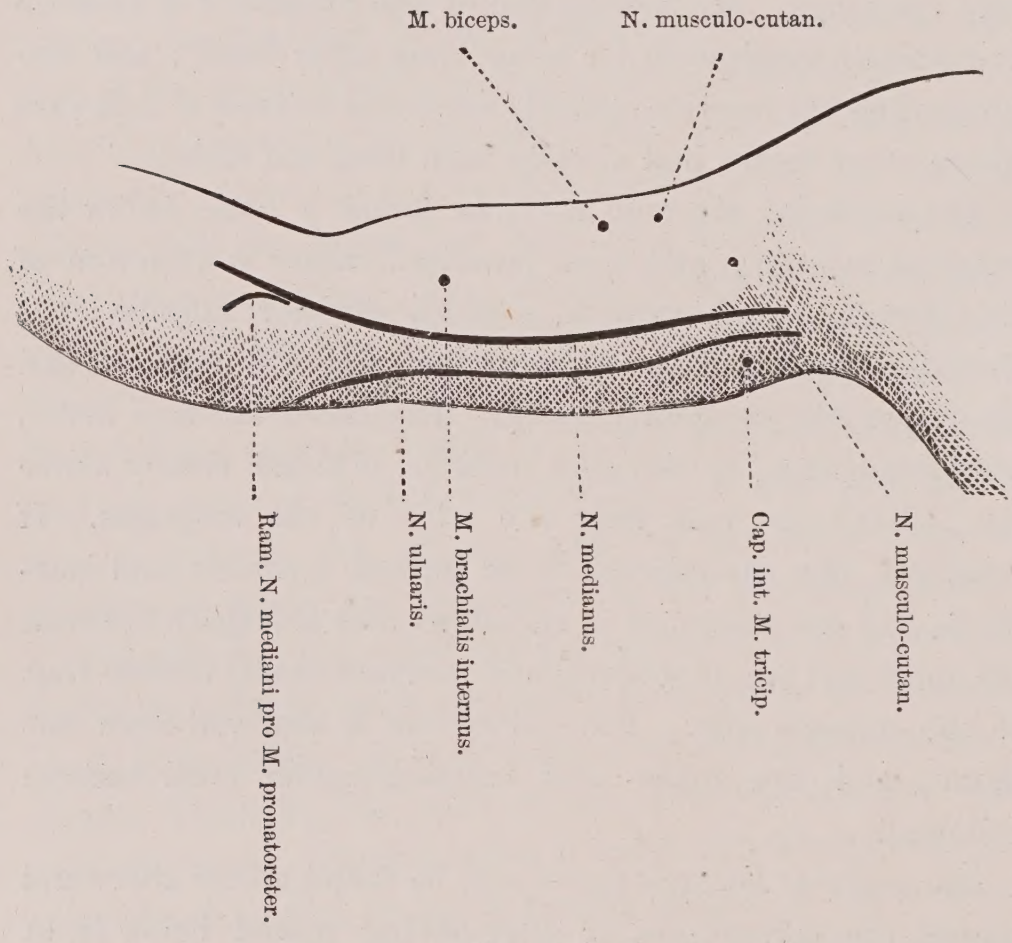

FIG. 129.

radialis internus, palmaris longus, flexor digitorum sublimis et profundus, the muscles of the ball of the thumb, and the first three lumbricals. The fore-arm is pronated, the hand flexed towards the radial side, the fingers flexed, and the thumb opposed. At the fore-arm this nerve is found quite superficial, about an inch above the wrist, between the tendons of the radialis internus and palmaris longus muscle. If faradised

in this place, the thumb is abducted and opposed, and the fisrt phalanges of the index and second finger are feebly flexed.

The *pronator teres* muscle receives one branch from the external, and another from the internal side of the median nerve at the bend of the elbow. The flexor digitorum sublimis and profundus muscles have to be directly faradised, as their nerves are not superficial; while branches for the

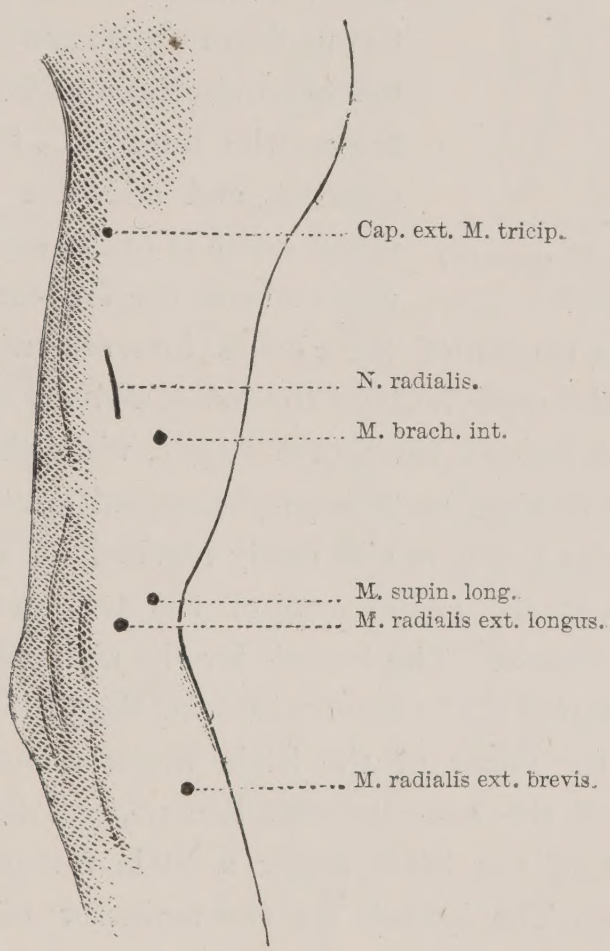

FIG. 130.

radialis internus and palmaris longus muscle may be discovered at nearly the same level below the elbow. The flexor pollicis longus may be faradised by putting the electrodes above the wrist, between the tendons of the radialis internus and supinator longus muscles.

The branches of the median nerve for the abductor pollicis

brevis, opponens pollicis, and flexor pollicis brevis, are found close together. The branches for the lumbrical muscles are likewise easily discovered.

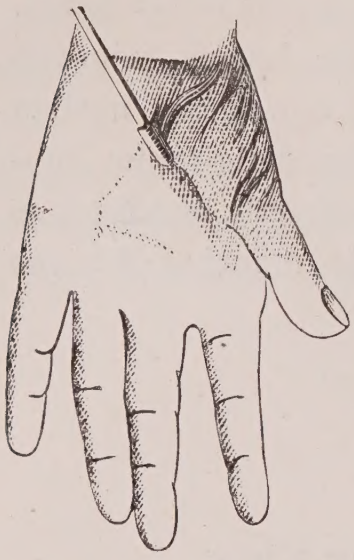

FIG. 131.—M. opponens pollicis.

The *ulnar nerve* is best faradised in the space between the olecranon and internal condyle. This proceeding causes contractions of the ulnaris internus, flexor digitorum profundus, palmaris brevis, the muscles of the fourth finger, the interossei, the lumbricalis quartus, and adductor pollicis. The ulnar nerve is quite superficial on the ulnar side of the fore-arm, at the radial side of the tendon of the ulnaris internus muscle. Faradisation of the same hollows the hand, adducts the thumb, and flexes and opposes the fourth finger, while the other fingers are flexed in their metacarpo-phalangeal joints.

The ulnar nerve is also easily reached on its way towards the wrist, at the radial side of the tendon of the ulnaris internus muscle. The branch for the abductor of the little finger is found at the external side of the pisiform bone; that one for the flexor of the little finger about half an inch in front of the hamulus ossis hamati, and that one for the opponens of the little finger a little further inwards and forwards. The branch for the adductor of the thumb is reached between the metacarpal bones of the first and second finger.

The interossei muscles may be directly faradised on the back of the hand, and each one of them will answer separately to a faradic current of moderate power. A stronger current causes likewise contractions of the internal interossei, whereby the fingers are stretched, and the first phalanx flexed towards the metacarpus.

The *radial nerve* is most accessible at the junction of the two upper thirds with the lower third of the humerus, at about the middle between the insertion of the deltoid muscle and the external condyle, and a little outwards from that

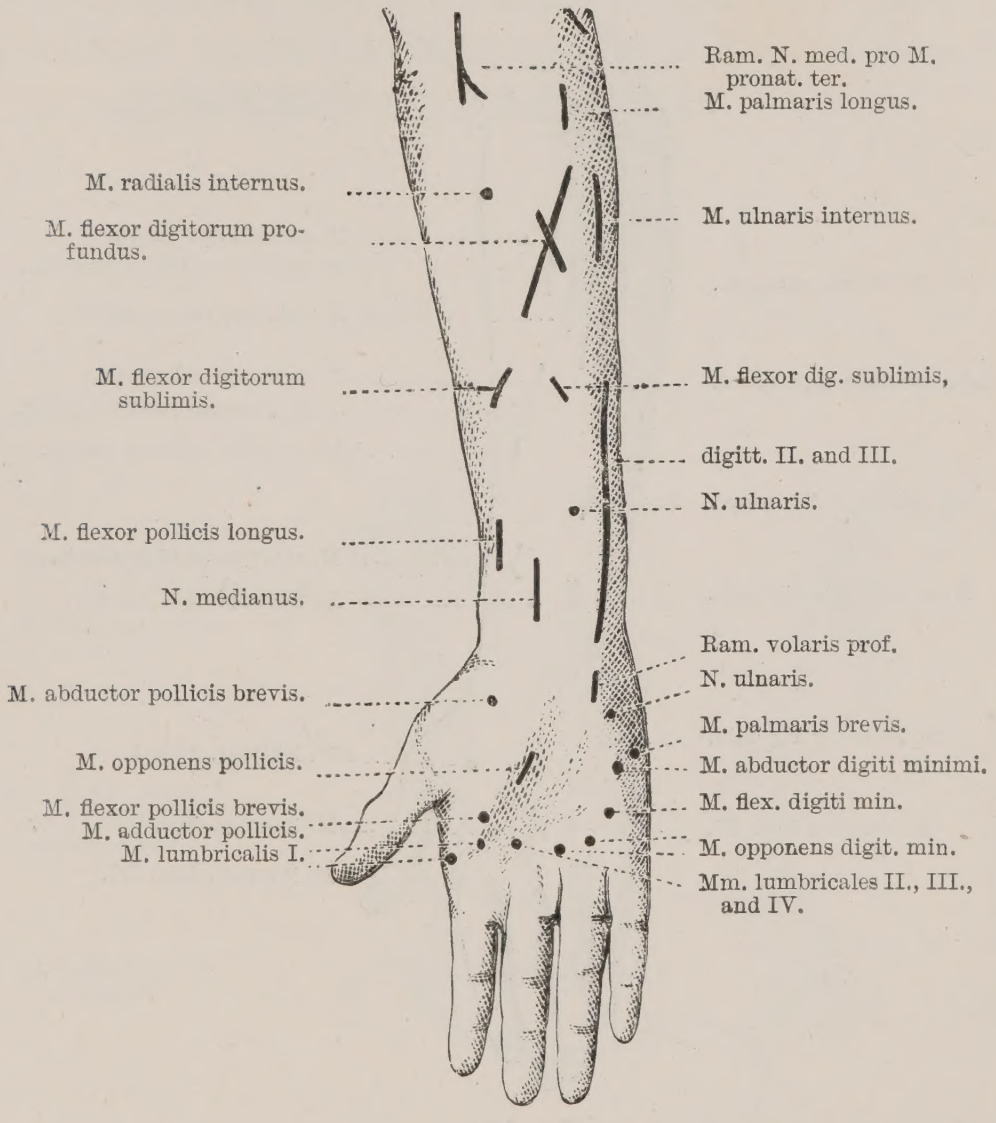

FIG. 132.

point. The triceps muscle is best directly faradised, as the branches given to it by the radial nerve are not superficially situated. The same holds good for the supinator longus muscle. Faradisation of the radial nerve causes contractions of the supinator brevis, ulnaris externus, radialis externus, extensor digitorum communis, extensor indicis et digiti

minimi proprius, extensor pollicis longus and brevis, and abductor pollicis; therefore we see supination of the forearm, with extension of the hand and thumb, and extension of the first phalanges of the other fingers.

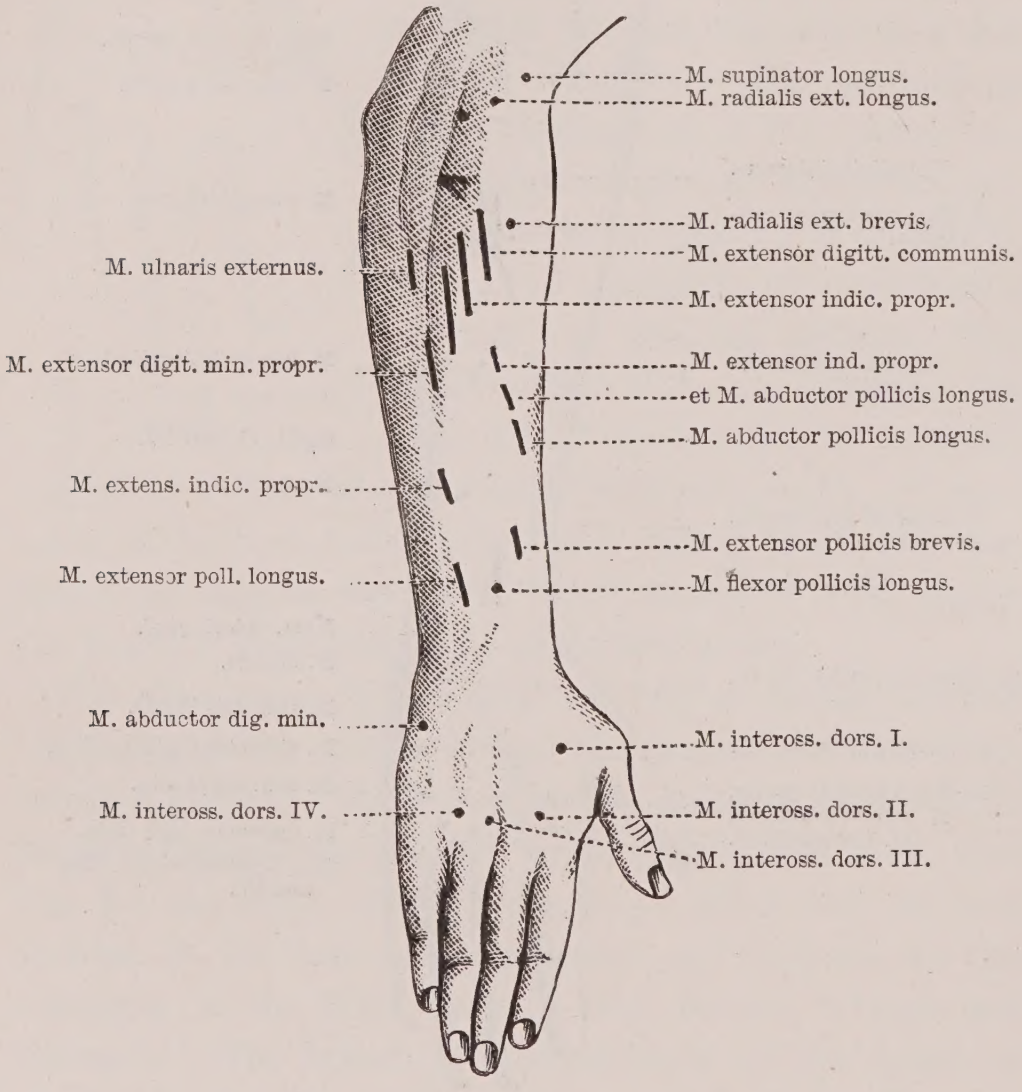
M. supinator longus.
M. radialis ext. longus.
M. radialis ext. brevis.
M. extensor digitt. communis.
M. ulnaris externus.
M. extensor indic. propr.
M. extensor digit. min. propr.
M. extensor ind. propr.
et M. abductor pollicis longus.
M. abductor pollicis longus.
M. extens. indic. propr.
M. extensor pollicis brevis.
M. extensor poll. longus.
M. flexor pollicis longus.
M. abductor dig. min.
M. inteross. dors. I.
M. inteross. dors. IV.
M. inteross. dors. II.
M. inteross. dors. III.

FIG. 133.

The extensor communis digitorum receives two branches, but in most persons direct muscular faradisation is necessary. By it the hand and fingers are extended, and the latter separated from one another, while the last phalanges remain slightly flexed, being quite independent of this muscle, and obeying the influence of the interossei. The ulnaris externus

muscle is also best directly faradised. The anconæus quartus receives two small branches from the radial nerve, which, when faradised, cause feeble extension of the fore-arm. The abductor pollicis longus receives a branch which, when faradised, causes the first and second phalanx of the thumb to be abducted towards the radial side. Most of the other muscles are only accessible to direct faradisation.

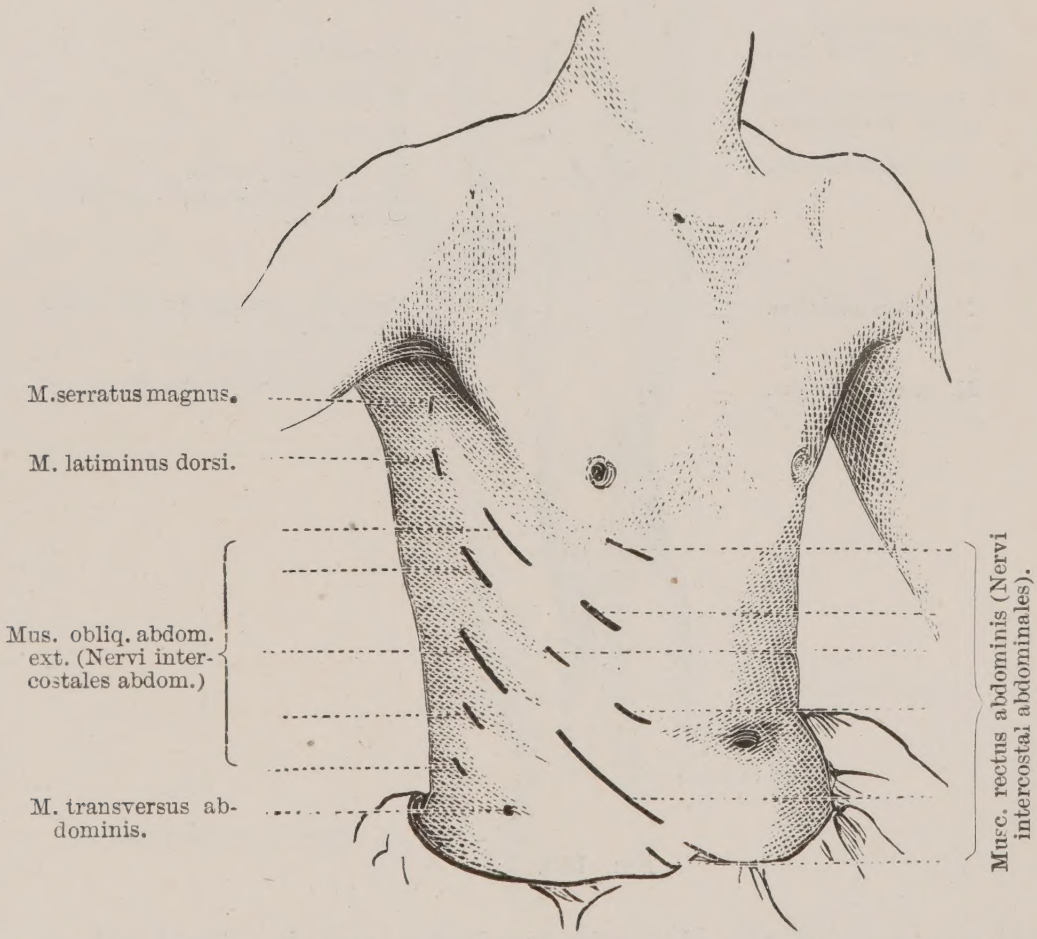
M. serratus magnus.
M. latiminus dorsi.
Mus. obliq. abdom. ext. (Nervi intercostales abdom.)
M. transversus abdominis.
Musc. rectus abdominis (Nervi intercostal abdominales).

FIG. 134.—Muscles of the Trunk.

Muscles of the Trunk.

The external intercostal muscles may be faradised by pressing a fine electrode against the lower border of the rib, near the origin of the serratus magnus; they cause a plainly perceptible elevation of that rib which is below the electrode,

and the one following the latter. The movements of respiration do not alter these phenomena.

The intercostal abdominal nerves may be separately faradised in the intercostal spaces. The rectus abdominis receives motor branches at its external border, while further on these are covered by the obliquus abdominis muscle. The

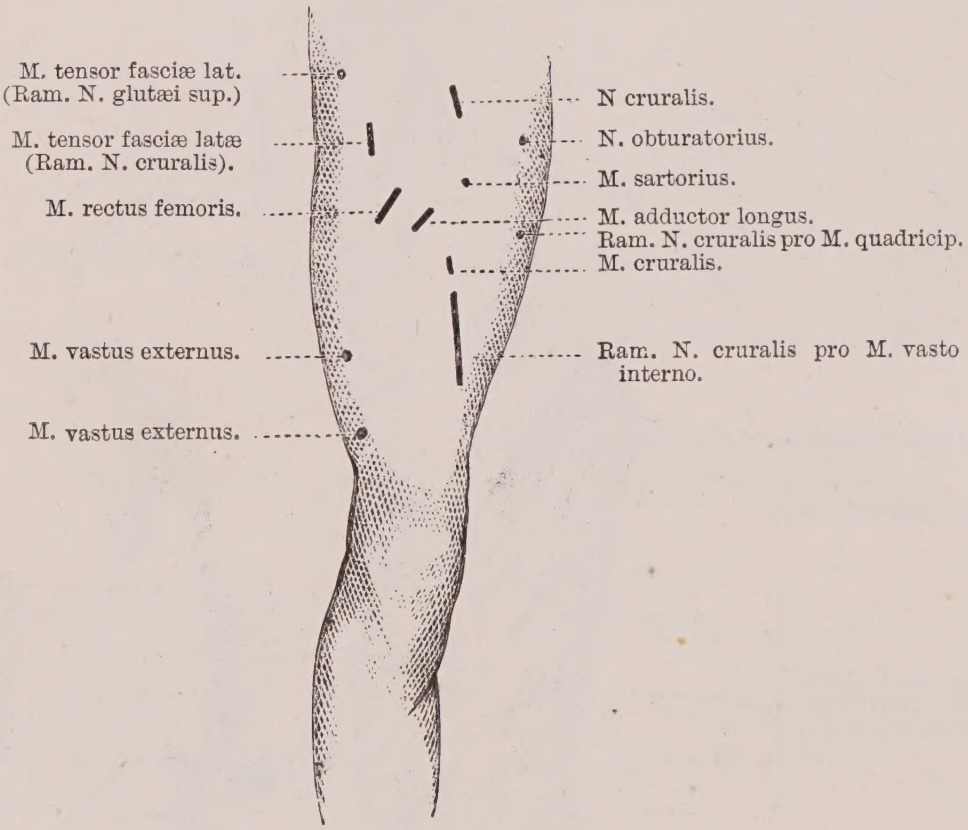

Fig. 135.

other nerves of the abdominal muscles may be faradised on the points indicated by the diagram.

Muscles of the Lower Extremities.

The muscles of the hip and thigh require more faradic power than other muscles, because the skin and the panniculus adiposus covering them are thicker, and the proportions of the muscles themselves larger. The leg, however, is

much more sensitive to faradism than the thigh. Slight variations in the course of the motor nerves are of frequent occurrence.

The *crural* nerve is easily discovered in the groin, and when faradised causes extension of the leg. The chief branch,

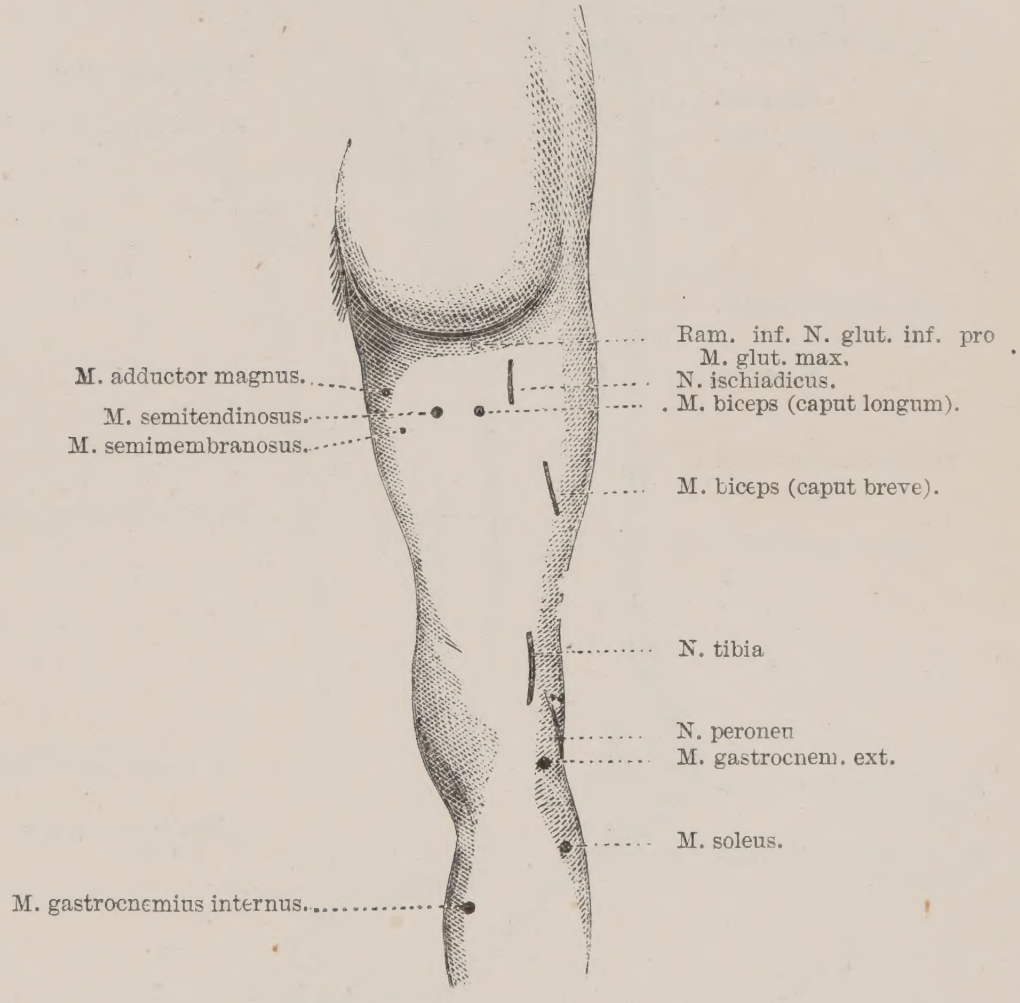

FIG. 136.

which animates the rectus, is found at the inner border of the muscle. The position of the branches for the other muscles is pointed out in fig. 136. The *obturatorius* nerve may be reached by placing the electrode vertically to the ramus horizontal pubis; or more easily to the inner and posterior circumference of the thigh.

The *glutæal nerves* are too deeply situated to be reached by the faradic current, but intra-muscular faradisation causes decided contraction of the glutæi muscles. The *sciatic nerve* may be faradised between the trochanter major and the tuber ischii, and causes flexion of the leg, with contraction of all

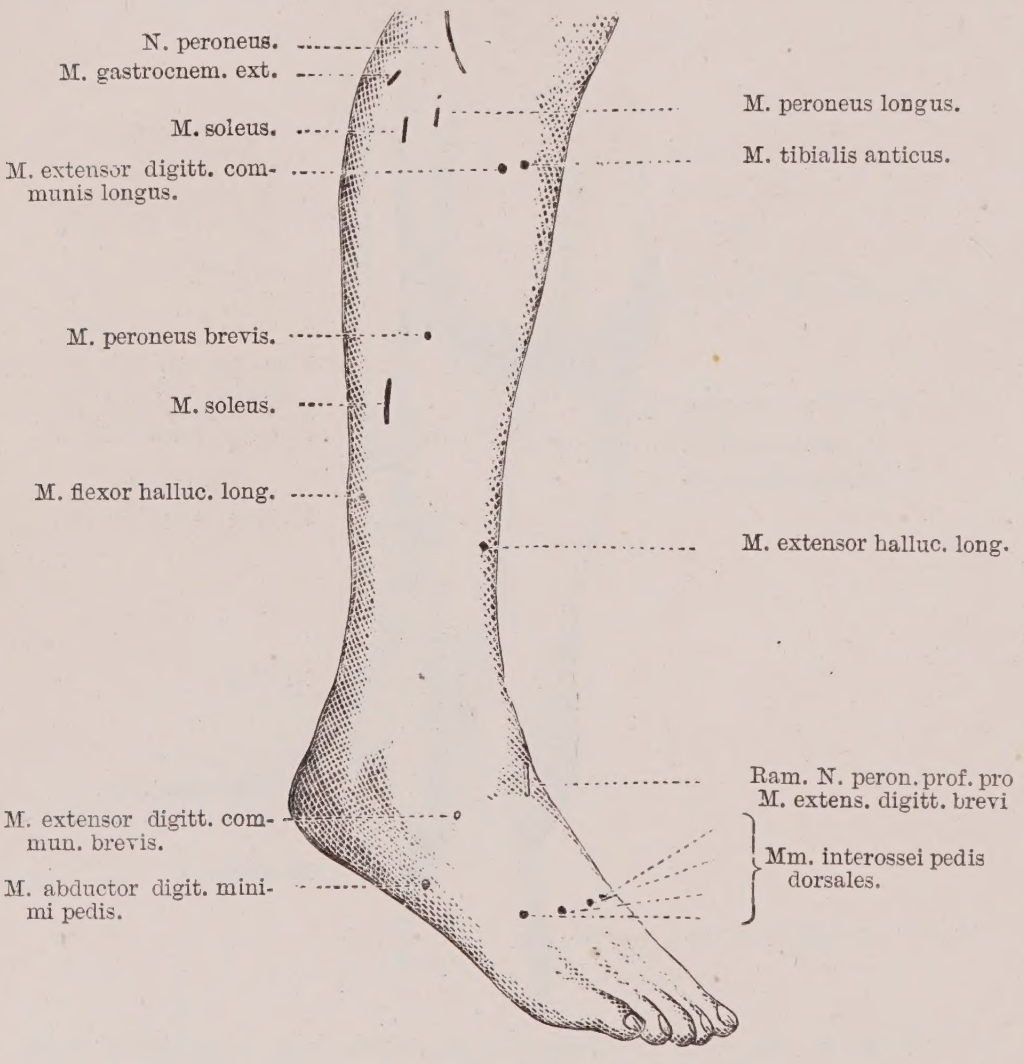

FIG. 137.

the muscles of the leg and foot. A powerful current is necessary for this, because the nerve is covered by the large flexor muscles of the thigh. The points for faradising the muscles on the back of the thigh are seen in the diagram.

The *peroneal* nerve is accessible at the posterior circumference of the capitulum fibulæ, while the *tibial* may be

faradised in the middle of the posterior surface of the knee-joint. Faradisation of the peroneal nerve causes contraction of the peroneal muscles, the tibialis anticus, extensor digitorum communis longus and brevis, and extensor hallucis longus. The motor points for the several muscles in front of the leg are shown in the annexed figure. Faradisation of

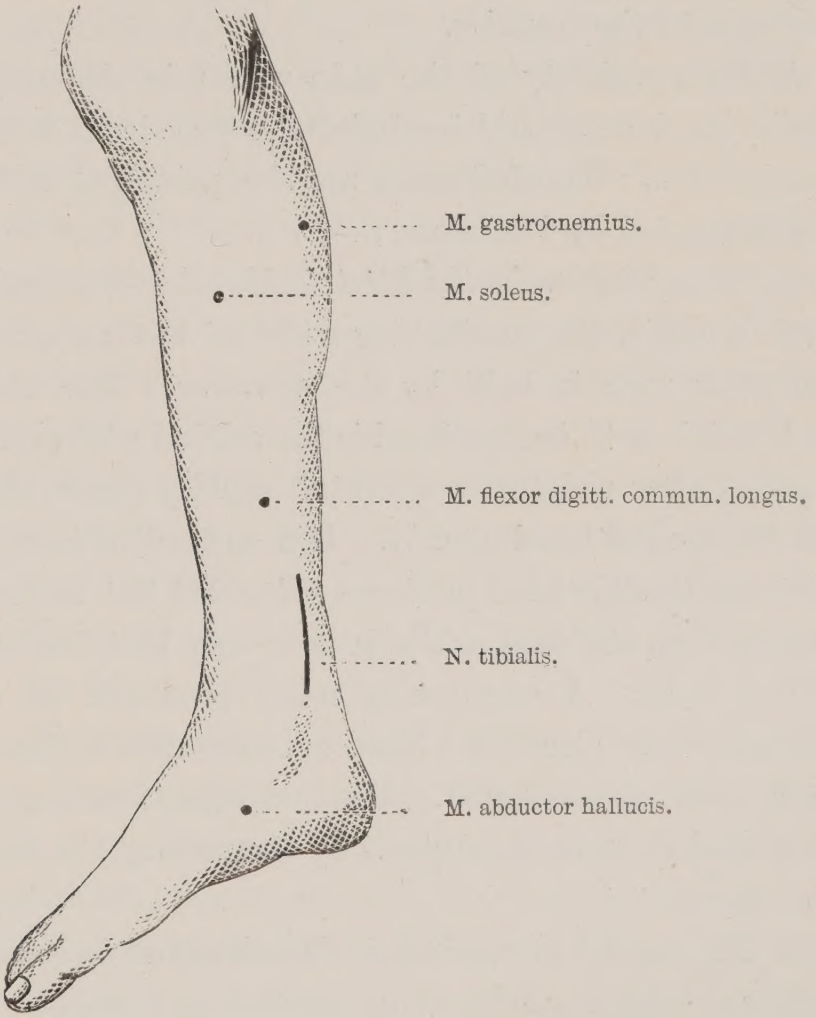

FIG. 138.

the tibial nerve causes contraction of all the muscles at the back of the leg and the sole of the foot. The motor points for the gastrocnemius, soleus, flexor digitorum communis longus, and abductor hallucis, are shown in Fig. 138.

2. *Faradisation of the Skin.*—By this proceeding we are

able to excite the sensibility of the nerves of the skin in the highest degree without injuring that organ. If a current of high tension be applied to the skin by means of a wire brush, erythema is produced, which disappears soon after the application; but destructive effects are never caused. For faradising the skin, this as well as the conductors should be dry; for, if it be moist, the electric current traverses it and proceeds to the muscles.

As the sensibility of the skin varies in different parts of the body, there should be different proceedings for cutaneous faradisation. The following are the principal methods of it recommended by Duchenne:—

a. *Faradisation by the Electric Hand.*—The patient takes hold of one of the conducting wires of the apparatus, while the other wire is held by the operator. The skin of the part which is to be faradised is then dried with a little violet powder, after which the operator rapidly passes the back of his disengaged hand over it. If a current of some power be used, the electric hand produces a decided but rather pleasant sensation on the face, while it acts only little on other parts of the body. A crepitating noise produced by the rapid passage of the electrified hand over the skin is there the only perceptible phenomenon. Distinct sensations may, however, be caused even in those parts by increasing the intensity of the current.

b. The second proceeding is *faradisation by solid metallic directors*, which are fixed on insulating handles. The skin should be dry, as before; but if the epidermis be very thick or hard, as it is on the palms of the hands and the soles of the feet, it may be slightly moistened in order to diminish the resistance. Where it is necessary to cause a powerful effect on one particular point, the electrodes are held for some time continuously in contact with the skin. Solid metallic directors, though acting energetically on the skin

of the face and the trunk, are often insufficient for the hands and feet, whatever may be the intensity of the current.

c. In such cases fine *metallic wire-brushes* are employed, which are likewise fixed on insulating handles. The skin should be lightly touched by these wires, but sometimes it is necessary to leave them longer in contact with it. This proceeding is exceedingly painful, and if the proposal to substitute electric shocks for the 'cat' as a punishment in the army were ever carried into effect, faradisation of the skin by metallic wire-brushes, with the maximum power of a good apparatus, would be the best method for it.

I have already alluded to the exquisite faradic sensibility of the skin of the face. A current of low tension applied there causes an effect which is not felt in any other part of the body. Faradic sensibility is stronger near the middle of the face—that is, in the eyelids, the nose, and the chin—than on the cheeks. On the forehead there is not so much sensibility as on the face, and on the scalp still less. The neck and trunk are more sensitive than the extremities; the cervical and lumbar region more than the other portions of the back; the inner and anterior surface of the extremities more than the external and posterior parts of the same. The skin of the hands and feet is only affected by a current of high tension. Faradisation of the skin has proved useful in cases of anæsthesia, neuralgia, and hysterical paralysis.

3. *Faradisation of the Internal Organs.—The membrana tympani* may be faradised in certain cases of nervous deafness, more especially if the continuous current should have failed to do good. The proceeding is the same as that adopted for galvanisation of the auditory nerve; the negative electrode should be in the ear, and the positive outside. A reverse arrangement of the poles does not produce the characteristic physiological effects which have been previously described.

In cases of loss of smell, a gentle induced current may be applied to the *mucous membrane of the nose*, especially if the practitioner does not possess a constant battery. A moistened director is placed on the nape of the neck, and an insulated conductor with a metallic top conducted over the whole of the Schneiderian membrane. For stimulating the *optic* and *gustatory* nerves, however, the continuous current must be employed, as faradism has scarcely any effect on them.

Faradisation of the *rectum* and of the muscles of the *anus* has been used for the cure of atony of that portion of the bowel, prolapsus ani, &c., and may be useful where want of muscular tone is the cause of the disorder. A conductor which has been previously described (p. 325) is introduced into the rectum, and connected with one of the poles of the

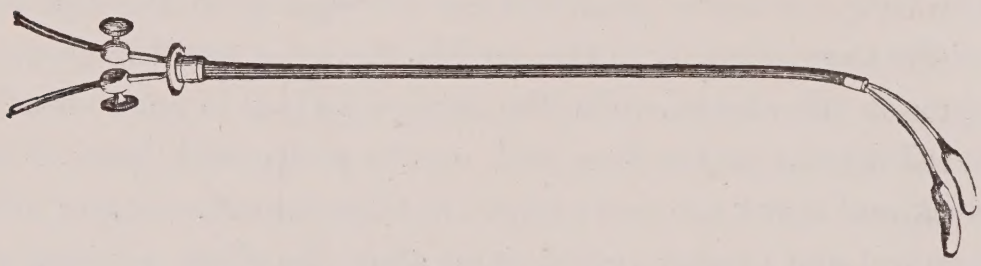

FIG. 139.—Duchenne's Double Electrode for the Bladder.

apparatus; another moistened electrode being applied outside, near the anus. Previous to this operation the rectum should be cleared out by enemata. The anus of healthy persons is extremely sensitive to faradisation, so that even a feeble current applied to it may cause tenesmus; but where there is much want of tone in this part, even a powerful current is borne without inconvenience.

Faradisation of the *bladder* is sometimes useful in atony and paralysis of that organ. For this purpose Duchenne has recommended an instrument (Fig. 139) composed of two flexible metallic wires, contained in an india-rubber tube with a double channel, so that they are insulated from one another. That end of the instrument which is to be introduced into

the bladder is so shaped that the wires, on being approached to each other, present the form of an ordinary catheter. When the instrument is in the bladder the outer ends of the wires are moved forward for about an inch or so, whilst the india-rubber tube remains in its place, and the inner ends of the director are thus removed from each other. The bladder should be emptied before the operation, as otherwise the neutralisation of the two contrary electricities would not be effected through the muscular tissue of the organ. When the conducting wires of the apparatus are connected with the outer ends of the wires of the director, the current will pass through the tissue of the bladder. Duchenne's instrument, however, is too complicated and easily gets out of order, so that it is much better to introduce into the bladder a simple director, such as has already been described for galvanisation of the urethra, the bladder being at the time filled with urine, and to place an ordinary moistened electrode to the perinæum, or over the os pubis.

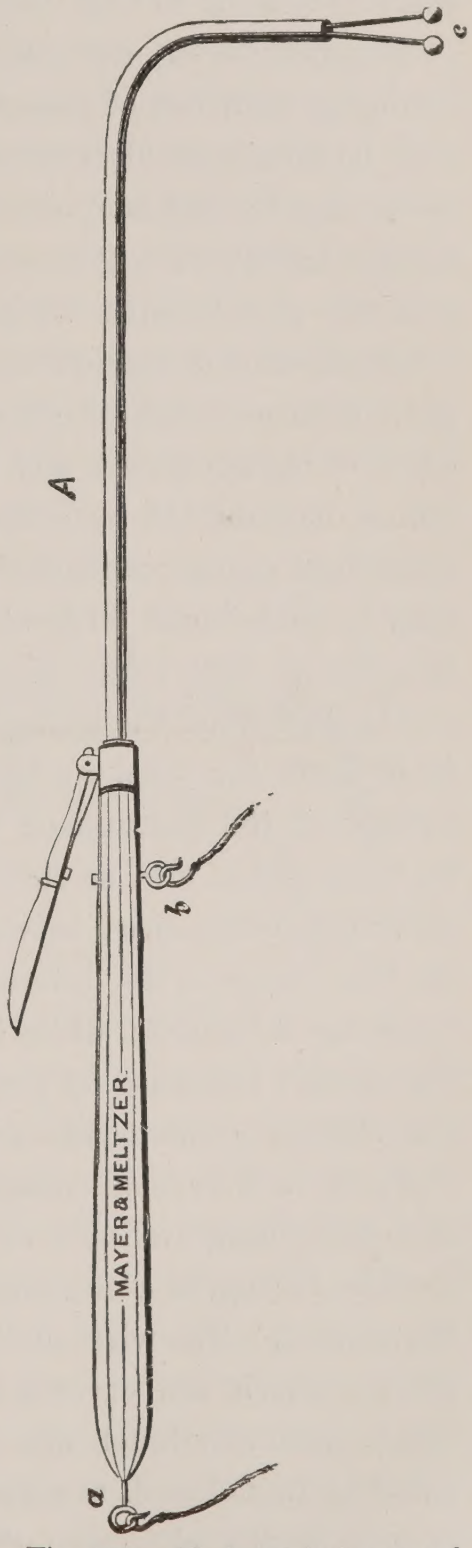

Fig. 140.—Mackenzie's Laryngeal Electrode.

The muscles of the *pharynx* may be faradised with a director similar to that used for other internal organs.

Faradisation of the *larynx* has proved useful in aphonia resulting from loss of power in the vocal cords. The larynx may be faradised directly or indirectly. Direct faradisation of the larynx has been chiefly practised by Dr. Morell Mackenzie and Prof. v. Ziemssen. One electrode is introduced into the glottis, with the aid of the laryngoscope, while the other director is applied externally. Dr. Mackenzie lets the patient wear a necklet connected with one of the conducting wires of the apparatus, and then introduces a metallic sound, which is insulated by india-rubber, and ends in a piece of moistened sponge connected with the wire. This instrument may be introduced without faradising the parts with which it may at first come in contact; for the circuit is only established when the sponge is, in the laryngeal mirror, seen to be upon the vocal cords, after which a little spring in the handle of the instrument is touched. The necklet should be worn rather low, so that it covers the sides of the cricoid cartilage and the space between it and the thyroid. By acting in this manner, the lateral adductor muscles of the vocal cords are faradised; while the central adductor may receive the faradic influence by placing the conductor on the posterior surface of the arytænoid cartilages.

Prof. v. Ziemssen considers Dr. Mackenzie's instrument not sufficiently reliable or suitable, and uses therefore a double laryngeal electrode, which he thinks preferable to the former. The wires of this instrument terminate in small knobs, which are covered with moistened sponge. Both knobs generally touch one another, so that when the instrument is introduced, the current does not reach either the mouth or the pharynx. The two branches are separated when above the larynx by pressing the first finger on a lever, which causes rotation of one branch. The excursion of the

lever, and therefore the distance of the two points from one another, is determined by a moveable screw which acts on the lever from above. The instrument is so solidly made that firm pressure may be made outwards, with both branches. This is necessary because the constrictor faucium medius and inferior, when faradised, compress the branches of finer instruments. On withdrawing the finger from the lever, the branches of the instrument are again made to touch one another, so that the electrode may be taken out of the pharynx and mouth without acting on these latter parts. Ziemssen, however, uses also a single electrode for localising the faradic current in certain muscles of the larynx.

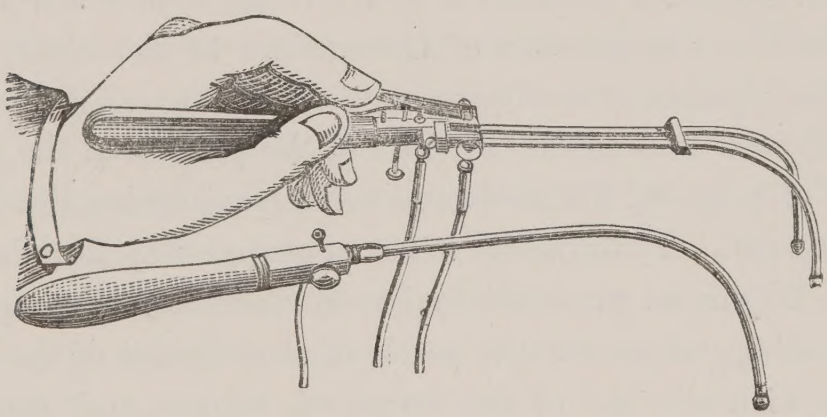

FIG. 141.—Ziemssen's Double Laryngeal Electrode.

Gerhardt [1] and Ziemssen [2] have endeavoured to determine whether the laryngeal branches of the pneumogastric may be faradised percutaneously at the neck. Gerhardt found that on observing the larynx with the laryngoscope during faradisation of the neck, near the upper and lower cornua of the thyroid cartilage, the closure of the glottis, and the tension and vibrations of the vocal cords were not altered, nor that the pitch of a tone which was sung underwent any change; he saw, however, that the vocal cords separated in a jerky manner when a vowel was pronounced; and that the

[1] Virchow's Archiv, vol. xxxvii.
[2] Loc. cit. p. 263.

glottis did not assume its normal width during inspiration. Ziemssen thinks that these phenomena are not owing to direct faradic stimulation of the recurrent nerves, but only to the action of faradism on the larynx generally. The same occurs if the larynx is cauterised or galvanised, without particular laryngeal nerves and muscles being acted upon.

Most physicians who occupy themselves specially with diseases of the throat, practise percutaneous faradisation. A powerful current is applied by means of a wire brush on a solid metallic electrode to the skin in front of the larynx, the circuit being closed by a moistened conductor placed on the nape or the side of the neck.

Prof. Ziemssen finds fault with Dr. Mackenzie for limiting the direct application of the current to the vocal cords and the arytaenoid cartilages, without having regard to the complicated anatomical relations of the parts, and the possibility of a special diagnosis and corresponding localisation of the current. To ourselves it has appeared that faradisation of the larynx, as practised by Dr. Mackenzie, is a compound proceeding, which consists partly of stimulation of the vocal cords, with the aid of the laryngeal mirror, and partly of faradisation of the skin by means of an extremely powerful current; and it is under these circumstances not always easy to decide, whether the result of the treatment is owing to the external or the internal application of faradism.

Ziemssen prefers intra-laryngeal to percutaneous faradisation of all the laryngeal muscles, with the only exception of the crico-thyroid, because these latter may be easily reached from without. When faradised, they cause the cricoid and thyroid cartilages to approach one another, while a tone, which is being sung, is raised half a tone, from increased tension of the vocal cords.

Intra-laryngeal faradisation is a difficult proceeding, both for the operator and the patient. The latter is chiefly

inconvenienced by pain, retching, vomiting, coughing, hypersecretion of mucus, temporary aphonia and other symptoms which it often takes weeks to overcome. But if doctor and patient persevere, the parts become at last so accustomed to the introduction of the instruments and to faradisation, that each single procedure may be carried on for about half a minute at a time. The operator is chiefly inconvenienced by the constant escape of the laryngoscopic image in consequence of the displacement of the parts, partly by reflex movements, and partly by the action of the current itself. The current used need not be stronger than one which will cause the frontal muscle to contract.

Ziemssen finds that of all the intra-laryngeal muscles the arytaenoides transversus is most easily faradised. When the point of the single laryngeal electrode has reached the posterior surface of the arytaenoid cartilages, the circuit is closed by the assistant putting an ordinary sponge-conductor outside. The muscle named then causes the posterior surface of the cartilages to project, and the two cartilages to be pressed against one another. A deficiency or incompleteness of this movement, in consequence of paralysis or paresis of the muscle, is a frequent as well as important cause of hoarseness and loss of voice.

The crico-arytaenoides lateralis muscle may be reached in the depth of the pyroform sinus, next to the external border of the cricoid cartilage. Its effect is to rotate the arytaenoid cartilage round its perpendicular axis, forwards and inwards, so that the processus vocalis and the free border of the vocal cord approach the mesial line. The thyreo-arytaenoides externus and internus muscles may likewise be faradised from the pyriform sinus, only the point of the electrode should be pressed downwards, inwards, and forwards, and its handle upwards and outwards. Faradisation of these muscles causes the arytaenoid cartilage to be displaced for-

wards and downwards. The crico-arytaenoides posticus muscle is situated on the posterior surface of the cricoid cartilage, at both sides of a rim in the middle of the latter. Faradisation of this muscle causes rotation of the arytaenoid cartilage round its axis outwards, and displacement of the same

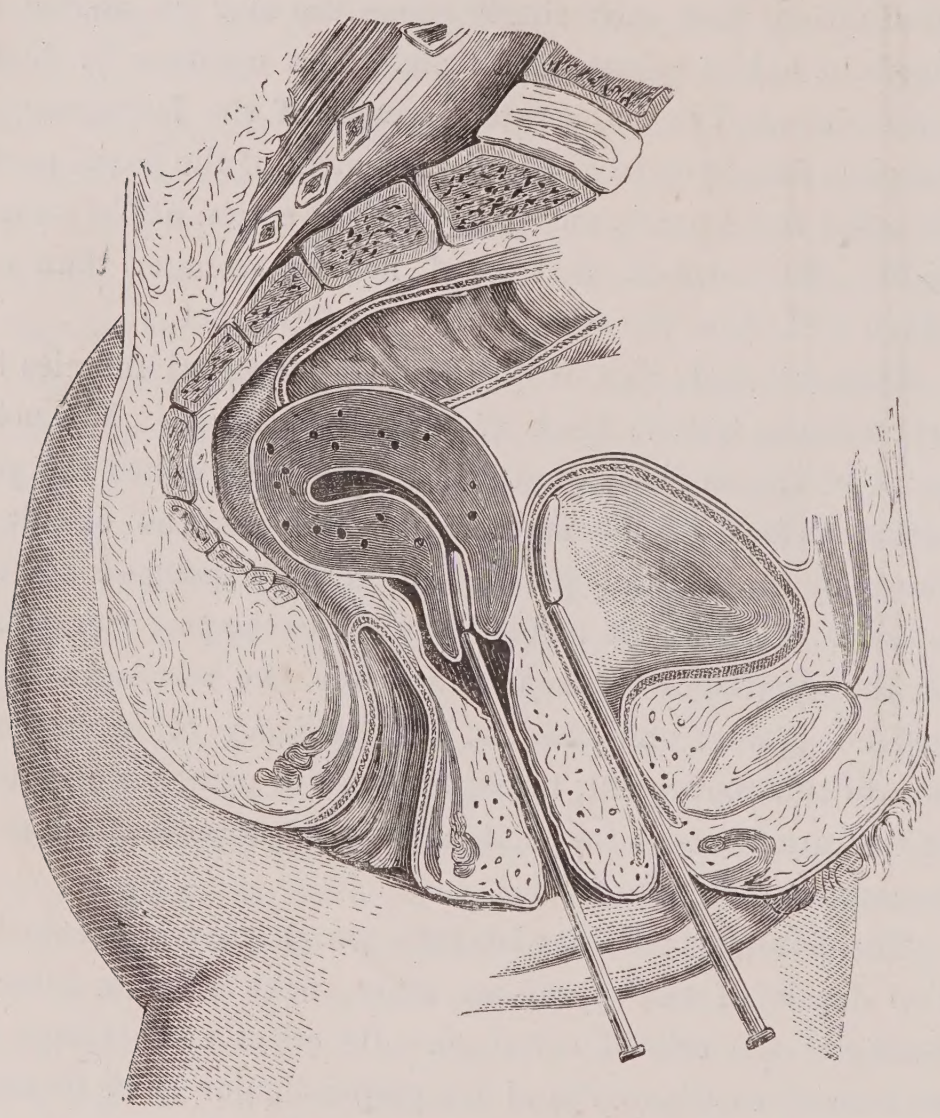

FIG. 142.—Faradisation of the Womb.

backwards and outwards, so that the glottis is entirely opened. If it be attempted to sing a tone while one of these muscles is faradised, only an impure deep sound is heard, inasmuch as the vocal cord of the faradised side does not bulge forward, but only that of the opposite side is seen to execute that movement.

The muscles of the *epiglottis*, which are animated by the superior laryngeal nerve, viz. the thyreo- and ary-epiglottici,

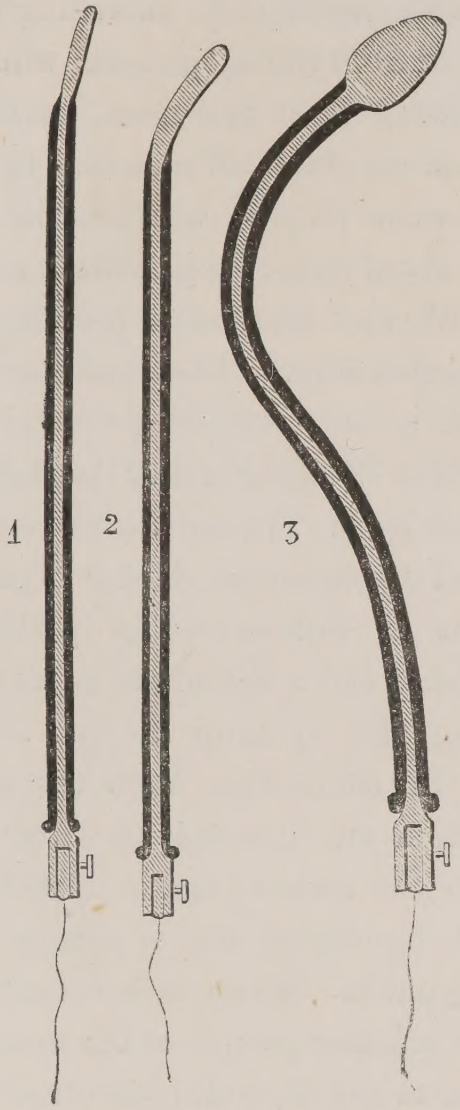

FIG. 143.— Simple Visceral Directors.

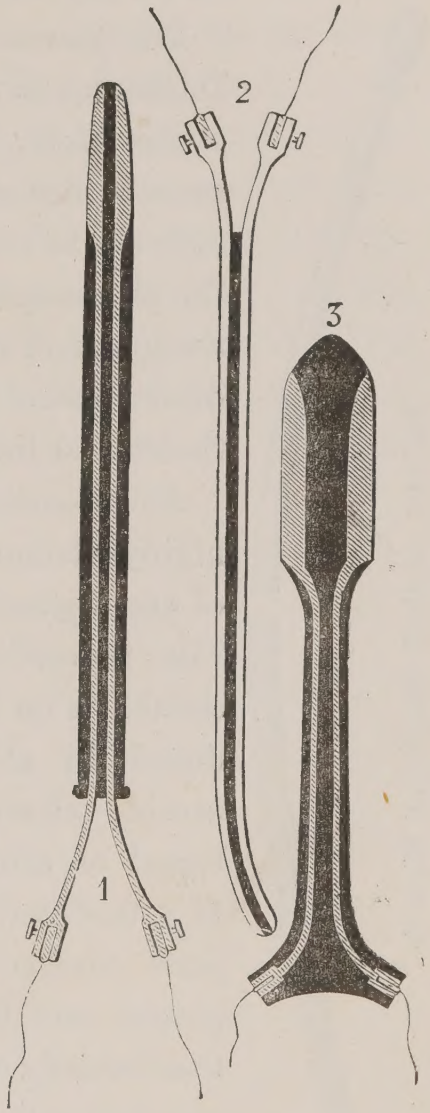

FIG. 144.—Double Visceral Electrodes.

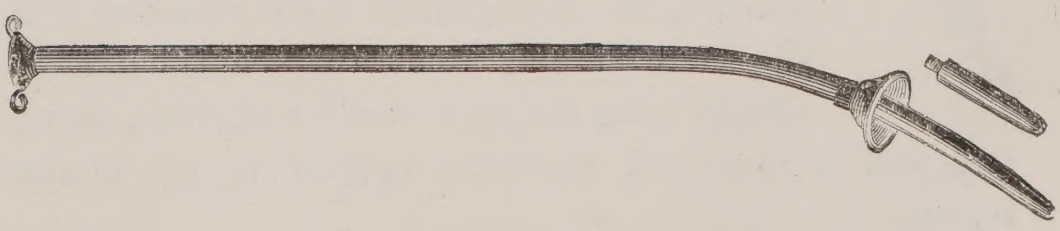

FIG. 145.—American Uterine Electrode.

may be faradised either directly by putting the electrodes,

on the lateral parts of the base of the epiglottis, or by stimulating the internal branch of the superior laryngeal nerve, on its way through the sinus laryngo-pharyngeus.

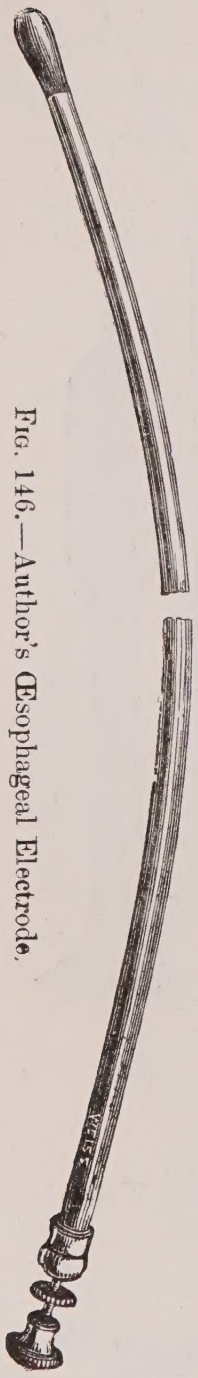

Fig. 146.—Author's Œsophageal Electrode.

The *pneumogastric nerve* may, according to Duchenne, be reached from the œsophagus; while others prefer faradising it at the neck, on the inner border of the sterno-mastoid muscle. It is difficult to see for what purpose faradisation of the pneumogastric should ever be practised, and the question from where it had better been faradised appears to us, therefore, to be one of purely theoretical interest.

Faradisation of the Womb (Fig. 142) has been highly recommended by M. Tripier[1] for the cure of engorgement and displacement of that organ. The proceeding is as follows:—The patient should lie on her back, and a speculum is introduced for allowing the operator to put the uterine electrode in connection with the external os, after which an olive-shaped director is introduced into the rectum, and a metallic plate covered with moistened lint or sponge is placed over the os pubis. Where it is intended to act chiefly on the anterior portion of the womb, one electrode is put to the os, while the other is introduced into the bladder, as shown in Fig. 142. In unmarried women, or where, in the married, the engorgement is not combined with displacement, the womb may be faradised by simply using the plate over the os pubis, as before, and a moistened conductor applied to the lumbar region.

[1] Manuel d'Électrothérapie, p. 548. Paris, 1861.

Fig. 143 shows the simple visceral directors for uterus, bladder, and rectum, and Fig. 144 the double electrodes for the same organ, as used by M. Tripier.

Fig. 145 is the uterine electrode made by the Galvano-faradic Manufacturing Company in New York.

Faradisation of the Œsophagus will only rarely be required; but I have used it successfully in a case of paralysis of the muscular fibres of that organ, with consequent difficulty of swallowing. In such cases a long and flexible insulated sound with a metallic top (Fig. 146) is introduced to the point where the impediment is found, and the circuit is closed by putting another moistened electrode to the chest or back.

CHAPTER IV.

ELECTRICITY AS A MEANS OF DIAGNOSIS.

THE different forms of electricity may be utilised for diagnosis :—

1. In paralytic affections ;
2. For detecting malingerers ;
3. For the discovery of projectiles which have been lodged in the body ; and,
4. For deciding between real and apparent death.

I.—ELECTRO-DIAGNOSIS OF PARALYTIC AFFECTIONS.

After faradism had been used for some time in the treatment of paralysis, it was observed that the muscles which were no longer under the influence of volition responded in some instances readily to the current, while in other cases no, or only very feeble, contractions were obtained. Hence it was concluded that electricity might be useful as a means of diagnosis in certain obscure paralytic affections.

Every means of diagnosis, when first pointed out as such, has been over-rated, carelessly employed, and then pronounced to be worthless. Forty years ago the prejudice against auscultation was very strong in this country, chiefly in consequence of some young enthusiasts having brought the stethoscope from Paris, and having undertaken, without paying any attention to the general symptoms of the various cases, to form the diagnosis by the physical signs alone ; they were constantly in error, and their undue pretensions brought discredit on the whole system. The same has been the case

with the microscope, the ophthalmoscope, the laryngoscope, and other valuable instruments: nor has electricity been exempt from this fate. Observations on the excitability of the paralysed nerves and muscles were carelessly made, conclusions hastily drawn, and thus the greatest confusion produced. As an instance, it may be mentioned that in August 1850, M. Martinet read a paper before the Paris Academy of Medicine, in which he stated that the presence of electro-muscular contractility was the distinctive character of cerebral, hysterical, and rheumatic paralysis, while its absence was an indication of disease of the spinal cord; yet all these assertions are incorrect!

No department of our subject is at the present time so little developed as that relating to the diagnostic value of the various forms of electricity. There can be little doubt that, as time advances, a more scientific use of galvanism and faradism will enable us to ascertain the exact condition of the nervous centres, the motor, sentient, and vasomotor nerves, and of the muscles, with far greater accuracy than we can do at present, and that electricity will thus become a most valuable test, not only in paralytic affections, but also in many other neuropathic and myopathic conditions. At present we may ascertain any alterations of the physiological law of contractions which have occurred; what is the influence of the direction of the current; whether during the application an increase or diminution of excitability becomes perceptible, &c. We are as yet, however, unable to determine any alterations of the current proper of the nerves, and of its positive and negative phases, which may have taken place; although it appears highly probable that such alterations occur in most diseases of the nervous system, and, if known, would make our treatment of them more scientific and more successful. Here there is therefore a large field open for future researches, which will no doubt yield abun-

dant results as soon as our appliances shall have reached that degree of perfection which is indispensable for such investigations.

1.—CEREBRAL PARALYSIS.

To Dr. Marshall Hall[1] the merit is due of having first directed the attention of the profession to the value of electricity in the diagnosis of paralytic diseases. He contended in a paper on the condition of the muscular irritability in paralytic limbs, that cerebral and spinal paralysis were in totally opposite conditions with regard to the excitability of the muscular fibre in the affected limbs. By cerebral paralysis he understood that which removes the influence of the brain—paralysis of spontaneous or voluntary motion, such as is produced by disease of the brain itself, or by disease of the dorsal portion of the spinal cord; while by spinal paralysis he designated that which removes the physiological influence of the cord. He stated that in cerebral paralysis the paralysed limbs were always moved by a slighter electric influence than that which was required to affect the healthy limb; or that if both limbs were moved, it was uniformly the paralytic limb which was more shaken than the other. In spinal paralysis, on the contrary, he found that the excitability of the muscles was diminished or even annihilated. This induced him to think that galvanism might afford a source of diagnosis between

1. Hemiplegia of the face, and
2. Paralysis of the facial nerve.

3. Hemiplegia of the arm or leg, and
4. Disease of the nerves of these limbs.

5. Disease of the spinal cord in the dorsal region and
6. Disease of the cauda equina in the lumbar region.

[1] Medico-Chirurgical Transactions, 1839.

Dr. Hall concluded that in cerebral paralysis the excitability of the muscular fibre became augmented from want of the application of the stimulus of volition, the brain being, in his opinion, the exhauster, through its acts of volition, of the muscular irritability; the spinal cord, on the contrary, being the special source of the power of the nerves of exciting muscular contractions, and of the irritability of the muscular fibre. In spinal paralysis, therefore, the irritability of the muscular fibre would be diminished, and at length become extinct, in consequence of its source being cut off. The same principle would explain the greater influence of certain respiratory acts (such as yawning, sneezing, coughing, &c.) on paralytic limbs, and also the greater susceptibility of the paralysed muscles to the influence of strychnia in cases of cerebral paralysis.

The first who objected to Marshall Hall's theory was Dr. Pereira,[1] who, in 1841, made a number of observations on paralytic patients, which convinced him that in certain cases of hemiplegia the muscles of the paralysed limbs responded very little to the electric current, while those of the healthy limbs were powerfully contracted. In 1845, Dr. Copland[2] stated that in cases of cerebral paralysis the affected muscles were not more excitable than the sound muscles, but, on the contrary, less so. The most elaborate criticism, however, of Marshall Hall's theory was given by Dr. Todd,[3] who refuted the view of the brain being the exhauster of muscular irritability, by pointing to the physiological fact that the healthy action of a muscle is promoted by exercise within reasonable limits, and that whatever restricts that exercise is injurious to the nutrition of the muscle, and consequently to its irritability. He afterwards adduced the evidence of thirteen

[1] Elements of Materia Medica and Therapeutics, 2nd edition. vol. ii. p. 1300.
[2] A Dictionary of Practical Medicine, vol. iii. part 1, p. 42.
[3] Medico-Chirurgical Transactions, 1847.

cases of cerebral paralysis, to prove that in certain morbid conditions of the brain the excitability of the muscles of the paralysed limbs was not augmented. Dr. Todd used the continuous current, electro-magnetism and magneto-electricity, and found that the results obtained were not affected by the instrument employed. He observed that in a certain number of cases the paralysed muscles responded readily to the galvanic stimulus, and even displayed a greater amount of vigour than those of the healthy limbs. In these cases the muscles of the palsied limb exhibited some degree of rigidity; and the vigour of their action in obedience to the galvanic stimulus was proportionate to the amount of rigidity within certain limits. In another class of cases electricity produced little or no contraction, and in these the muscles appeared more or less wasted. In a third class he found that, while the paralysis was almost complete, the galvanic stimulus excited equally the muscles of the paralysed and those of the healthy limbs; and these were generally cases of apoplexy occurring in persons previously healthy and not advanced in years.

Dr. Todd also concluded that the state of the *muscles* had comparatively little effect in the production of these phenomena, but that they depended upon the state of *nervous force* in the paralysed limbs. In cases where the stimulus produced little or no contraction, the force was *depressed* in the nerves of the paralytic limb; in cases where the galvanic current excited stronger contractions in the muscles of the paralysed limb than in those of the healthy limb, the nervous excitability was *exalted*; and in the third class, where there was no perceptible difference between the two, nervous excitability was *normal*. He therefore contended that galvanism might, in cases of hemiplegia, serve as a test to distinguish between an irritant and a depressing lesion of the

brain, but not as a means of distinguishing between cerebral and spinal palsy.

In 1850 M. Duchenne,[1] of Boulogne, recorded some observations on the state of electro-muscular sensibility and contractility, and strongly objected to the mode of experimentation employed by Marshall Hall, the only true way to arrive at a satisfactory result being, according to him, the localisation of the electric current in the tissue of the paralysed muscles. He stated that muscular contractility was normal in cerebral paralysis, there being no difference between the muscles of the healthy and of the paralytic limbs of such patients. This statement I can only explain by assuming that Duchenne tested the muscular irritability only in a limited number of cases of cerebral paralysis, and that these happened to be such as are described by Dr. Todd in the third class, in which the muscles retain their normal condition.

I have tested the nervous and muscular excitability in a very large number of cases of cerebral paralysis, and can fully corroborate Dr. Todd's observations. In some cases the excitability is diminished, the muscles are flaccid, and the nervous excitability depressed; in another class of cases the excitability is increased, there is early rigidity of the muscles, and an irritative lesion of the brain; and, finally, in a third class no difference is observed in this respect between the healthy and the paralytic limb. I have employed both modes of experimentation, viz. sending the current right through the limbs, and localising it in the affected nerves and muscles. They both yield nearly the same results; but local faradisation and galvanisation make the differences of muscular contractility appear far more striking.

[1] Archives générales de médecine, 1850. Vol. xxii. p. 4.

I shall now relate a few cases illustrative of the three classes which may be distinguished in paralysis resulting from cerebral disease.

CASE 1.—*Hemiplegia from cerebral hæmorrhage; muscular contratility diminished.*

R. V., aged 57, of originally vigorous and plethoric constitution, but now somewhat debilitated by antiphlogistic treatment; has never had any serious illness, with the exception of pneumonia, ten years ago, from which he soon recovered. Six months before I saw him (August 1857) he had an attack of cerebral hæmorrhage, accompanied with loss of consciousness for nearly three hours, and paralysis of the whole right side. Speech was not affected. He did not know of any cause of his affection, but mentioned that his father had died from paralysis. He had sometimes suffered from palpitations of the heart, but auscultation showed the heart to be healthy. The distortion of the face soon disappeared, and the muscles of the arm and leg also regained some mobility. He wrote, however, a very unsteady hand, and experienced great trouble in dressing and feeding himself; walking was very difficult.

His judgment and memory were not impaired; there was no pain in the head or limbs. The face and tongue were straight, and the movements of the eyes easy. The skin of the right side was cold and flabby. Pulse 76, weaker in the right than in the left radial artery. There was a feeling of numbness in the right arm and leg, which were not so sensitive to the prick of a pin as the limbs of the opposite side. The muscles of the same sides were relaxed and somewhat wasted, and the extensors more so than the flexors. There was no rigidity of the muscles, either in the upper or in the lower extremity. Passive extension of the fore-arm upon the arm, and of the leg upon the thigh, could be made without any resistance being offered by the muscles. The faradic stimulus, administered in moderate dose and with slow intermittences, did not cause the paralysed extensor muscles of the right arm to contract, while the corresponding muscles of the other side answered well to the current. The same was the case with the muscles animated by the peroneal nerve.

CASE 2.—*Hemiplegia from irritative disease of the brain; augmented muscular excitability.*

In December 1858, a grocer, C. K., aged 57, was under the care of Dr. Todd, in King's College Hospital; he had had repeated attacks of apoplexy, and probably suffered from a tumour in the brain, which kept up continual irritation. The patient suffered at that time from ptosis of the left upper eyelid, and from paralysis of the right side, with marked rigidity of the flexor muscles. I tested the excitability of the muscles, and found it slightly increased in the paralysed leg, and very much so in the paralysed arm. When I directed a gentle current to the extensor communis digitorum of the right forearm, a sudden and powerful extension of the fingers took place, which were before firmly closed by rigidity of the flexors; the same current directed to the left side did not cause any movements in the fingers, and much more power was required for producing the same amount of contraction in the healthy as in the paralysed side. It was also noticed that the *inverse* current excited somewhat stronger contractions in the *paralysed* side than the direct, while the *direct* current excited somewhat stronger contraction in the *healthy* side than the inverse. These experiments were repeated several times, and always with the same result, in the presence of Dr. Todd, Dr. Conway Evans, and a large number of students.

CASE 3.—*Hemiplegia from cerebral hæmorrhage; normal excitability of the muscles.*

L. T., a widow, aged 62, had long been in a gouty condition, and had an apoplectic attack seven years ago, in which she lost her speech and consciousness, and the use of the left side. After six months a gradual improvement took place, especially in the leg. When I saw her in November 1858, the speech was still impaired, walking troublesome, and the motion of the left thumb and forefinger very limited. Although these two fingers had then scarcely been used for seven years, the excitability of the extensor and abductor muscles of these fingers was quite normal, as they moved freely under the influence of a gentle current. The same was observed in the recti of the thighs.

2.—PERIPHERAL PARALYSIS.

Marshall Hall understood by *spinal paralysis* that which occurs when the muscle is functionally separated from the cord, as, for instance, by mechanical injury to a nerve. This peculiar view has been almost generally misunderstood; for most authors have looked upon Hall's 'spinal paralysis' as synonymous with paralysis from disease of the spinal cord. It is, however, evidently meant for those cases which are owing either to a mechanical injury to a nerve (traumatic paralysis), or from pressure by an effusion, which may be of a rheumatic, gouty, or syphilitic character. As much confusion has been produced by Marshall Hall's nomenclature, we think it best to drop the terms proposed by him, and substitute the word 'peripheral' for 'spinal' paralysis. Recent researches have thrown considerable light on the changes which occur in this form of palsy, as far as the galvanic and faradic excitability of the nerves and muscles is concerned, and have thereby enabled us to render both the prognosis and treatment of these affections more certain.

To M. Baierlacher[1] the merit is due of having first employed the continuous current as a means of diagnosis in such cases, and of having shown that *galvano-muscular* contractility may still exist after *farado-muscular* excitability has disappeared. He has recorded the case of a woman, aged 28, who suffered from paralysis of the portio dura of one side. Faradisation had no influence on the muscles, nor was there any change in this particular after three weeks' treatment. He then applied a continuous current of fifteen cells, which caused all the paralysed muscles to contract. After three such applications there was considerable improvement, and after four more the paralysis had almost entirely disappeared.

M. Schulz[2] has recorded several cases of facial palsy, in which

[1] Baierisches ärztliches Intelligenzblatt, 1859. No. 4.
[2] Wiener medicinische Wochenschrift, 1860. No. 27.

the induced current did not cause any contractions on the paralysed side, while a current of eight cells of Bunsen's battery caused the muscles to move on opening as well as on closing the circuit, whether the current was direct or inverse. A current of the same power did not affect the muscles of the healthy side. On increasing the power to twenty cells, however, the muscles of the healthy side responded both on opening and closing, yet even then the contraction was more powerful in the paralysed side. As time went on, the exalted excitability of the paralysed muscles gradually diminished, and at last completely disappeared. The diminution of galvano-muscular excitability occurred simultaneously with the recovery of the power of volition over the muscles; and at the same time the latter commenced to respond again to the faradic current.

Moritz Meyer[1] has observed the case of a woman, aged 48, who suffered from facial palsy of the left side, and where faradisation was quite ineffectual, while a continuous current of six cells caused all the muscles to move. The patient gradually recovered under the influence of the continuous current. Another similar case fell under the notice of Professor Ziemssen.[2] A young man, aged 18, had had facial palsy of the left side for three weeks. Faradism locally applied to all the facial muscles individually, and to the branches of the portio dura of the affected side, did not cause any contractions, even if a powerful current was used; the continuous current, on the contrary, caused regular and vigorous contractions on making the circuit in all the muscles, while on breaking it they responded feebly. The galvano-muscular contractions of the corresponding muscles on the healthy side were not nearly as powerful as those on the paralysed side; and the application of the continuous current to any paralysed muscle individually, or to the nervous fibre animating the same, did not restore its excitability to faradisation or volition. If very slow intermittences of the induced current were used, so that one closing and opening was used in two seconds, there was in the healthy side a strong contraction on closing, and a feeble contraction on opening the circuit in each muscle, while in the paralysed side there was no contraction at all, either on closing or on opening. A few weeks afterwards the deformity of the face had diminished, but the galvano-

[1] Die Electricität in ihrer Anwendung auf Medicin. 2te Auflage, 1861, p. 323.

[2] Die Electricität in der Medicin, 1866, p. 76.

muscular excitability was then much less, and at last disappeared altogether. In two months the left side had regained its voluntary power, with the exception that the eyelids could not be entirely closed; yet even then neither galvanisation nor faradisation caused any contractions. The same patient was examined two years and a half afterwards, when the face appeared quite healthy, during rest as well as during physiognomical expressions. Sensibility was considerably diminished on the left side. Faradisation caused contractions in all the muscles which had been previously paralysed, but the response was not nearly so strong as on the healthy side. The same condition was observed on applying the continuous current, eight cells of which caused distinct movements on the side which had not suffered, while no effect was produced on the other. On increasing the power of the current, the muscles of the affected side were seen to contract, but more sluggishly than those on the right. In another case recorded by the same observer the excitability of the motor nerves to volition, faradisation, and galvanisation, was completely abolished, while the paralysed muscles had preserved their irritability to the continuous current, and responded to direct galvanisation with a sluggish contraction.

I have observed a case of facial palsy which had been caused by an aural surgeon introducing a strong solution of nitrate of silver into the left meatus through a glass tube, and then blowing it through the Eustachian tube. This proceeding, which I consider most unjustifiable, caused at once excruciating pain in the head, and paralysis of all the muscles animated by the portio dura. I was consulted three months afterwards, when the paralysis remained complete. The muscles did not respond to faradism, but the continuous current caused them to move feebly on making the circuit. The patient remained three months under my care, being treated by galvanisation, and ultimately recovered. The galvanic excitability *increased* as time went on; faradic contractility had in a measure returned at the end of the treatment, but was still much more sluggish on the left than on the right side.

Meyer has found that those cases of facial palsy in which farado-muscular excitability is merely diminished, but not completely gone, generally recover within a few weeks; while, on the other hand, those in which faradisation produces no effects at all about a week after they have come on, and where a feeble con-

tinuous current causes vigorous contractions, have a worse prognosis, inasmuch as they only improve after many months of treatment, and even then do not quite recover. In these latter cases Meyer believes the seat of the paralysis to be in the facial nerve during its transit through the petrous portion of the temporal bone, and considers the galvano-muscular contractions as reflex movements produced by stimulation of the ganglion geniculatum. This latter hypothesis is, however, untenable.

Eulenburg has published the following case:—

A student, aged 21, on walking under a windmill which was in motion, received a superficial injury on the back of the head, and a violent blow against the right arm. The skin was not broken, but there was considerable extravasation of blood, especially in the lower third of the arm, and in the bend of the elbow. Immediately after the receipt of the blow there was complete paralysis and anæsthesia of the right radial nerve, which remained after the injury to the head had healed, and the extravasated blood absorbed. Electricity was used a fortnight afterwards, when the faradic contractility of the paralysed muscles, both extra- and intra-muscular, was found to be entirely gone. Galvanisation of the radial nerve in all directions had the same result. A bad prognosis was given, and neither motility nor electric contractility were ultimately regained.

M. Neumann,[1] when observing a case of this kind, conceived the idea of rapidly interrupting the continuous current by means of a mechanical contrivance in order to arrive at a rationale of these phenomena, and noticed that if the interruptions were very rapid, no effect was produced in the paralysed side, while the healthy muscles on the other side of the face responded as usual. From this he concluded that the duration of the current was of paramount importance in these cases. When this is more than instantaneous, the current has a greater effect on the paralysed than on the healthy muscles; but when the stimulation is merely instantaneous, no effect is produced even by a powerful current. He observed the same thing in the nerves and muscles of frogs which were dying. Before the excitability of these structures was quite gone, there was a stage which often continued for several hours, and in which the most powerful faradic current failed to produce con-

[1] Virchow's Archiv für Anatomie und Physiologie, 1864, p 54.

tractions, while a weak continuous current caused the muscles to move.

Brücker [1] has recorded several cases of fatty degeneration of the muscles, which confirm Neumann's statements. Faradisation failed to cause contractions, while with the continuous current of twenty cells a response took place on closing the circuit. He also observed that the contraction on closing did not occur so rapidly as it does in healthy muscles, but was somewhat retarded; that if the circuit was slowly opened and closed, the movements were more extensive than if there was a rapid succession; that if the direction of the current was quickly changed, the strength of the contractions increased; and that there was no effect at all if a current of instantaneous duration was applied. These facts were observed in the peroneal, crural, sciatic, and tibial nerves. M. Eulenburg [2] has assumed three different specific energies of the motor nerves, viz. the power to respond individually to volition, faradisation, and galvanisation; and thinks it probable that in certain conditions of changed molecular arrangement, one of the other of these energies, or even two of them, may be totally gone, while the third remains intact. This would be an analogy to the abolition of certain kinds of sensation, which is frequently observed in locomotor ataxy, where the sense of touch may be normal, while sensibility to pain or the sense of temperature may have completely disappeared.

Professor Erb,[3] of Heidelberg, has experimentally studied the conditions which are now under consideration, and has come to the important conclusion that in these alterations of excitability *nerves and muscles obey totally different laws.* In all cases of exalted galvanic excitability it is only the muscles which answer in this manner, and those observers are in error who have assumed the existence of increased galvanic excitability of the nerves, together with lost faradic excitability of the same. In fact, where there has been an injury to the motor nerves, their excitability appears

[1] Deutsche Klinik, 1865. No. 30.
[2] Deutsches Archiv für klinische Medicin, 1866. Bd. ii. Heft 1.
[3] Ibid. 1868. Bd. iv. p. 566.

to be completely gone, not only to the induced, but also to the continuous current.

Soon after the paralysis has set in, whether it be caused by rheumatic effusion or by contusion and division of the nerve, the excitability of the nerve to both forms of electricity begins to diminish. In one of Erb's cases this diminution was, during the first few days of the illness, preceded by a slight increase of it; and he thinks that this condition may be characteristic of rheumatic palsies. Soon afterwards, however, viz. in human subjects from the end of the first week, and in injured nerves of rabbits even before that time, a considerable diminution of excitability takes place, which proceeds gradually from the seat of the disease to the periphery, the point of entrance of the nerve into the muscle being the last to lose it. This decrease is shown in two ways, inasmuch as the power of the current required for causing a slight contraction has to be continually increased, and the contractions caused by even a strong current gradually diminish in vigour. Towards the end of the second week, faradic as well as galvanic excitability of the nerves has completely disappeared. The duration of this stage varies according to the cause of the palsy, the intensity of its effect upon the nerve, and the rapidity with which the process of regeneration is carried on. In rabbits, the nerves of which have been bruised, it lasts from five to six weeks: where the nerves have been divided, its duration is longer; and in facial palsy of rheumatic origin it may extend over many months, and even years. After a time, however, the excitability of the nerves is gradually restored. The statements of different observers regarding the mode in which the nerves regain their excitability vary considerably, and have led them to assume various groups and degrees of palsy, which are, however, not so distinctly separated in nature. In most cases there appear, simultaneously with the return of volun-

tary motion, traces of faradic as well as of galvanic excitability, although at first only if a high power be used. Both kinds of excitability seem to return almost simultaneously, and the contractions then become more vigorous from day to day, so that at last a feeble current is sufficient to make them plainly perceptible.

Cases in which the electric excitability is completely restored to its original standard are exceptional; for it generally remains somewhat below par. All these conditions do not appear to have any direct relation to the recovery of voluntary power.

The *muscles* follow totally different laws under these circumstances. Within the first few days of the palsy there is no decided alteration of direct galvanic or faradic excitability, and it is only towards the end of the first week that a diminution of it is observed. The *faradic* excitability continues to sink, whether the current be slowly or rapidly interrupted, and whether the primary or secondary current be used; *galvanic* excitability, on the contrary, commences to rise, and becomes within a few days exalted considerably beyond the normal standard, so that a much weaker current than is necessary for causing contractions in healthy muscles, will produce decided effects on the paralysed ones. We have already seen that this is owing to the physical difference of the continuous and induced current, it being the instantaneous duration of induction currents which renders them incapable of exciting the muscles, and a continuous current of equally instantaneous duration having no more effect than faradisation. At this period excitability is not only increased, but likewise altered in quality. When healthy muscles are acted upon by the continuous current, the cathode has more effect than the anode, and the closing contraction is stronger than the opening; while the anode produces effects chiefly on opening, especially after the current has acted for some

time. In paralysed muscles, on the contrary, the effect of the anode increases more rapidly and considerably than that of the cathode, so that it soon becomes equal to the latter, and sometimes even preponderates over it. At the same time the effect on closing becomes greater than that on opening; and finally, an effect takes place with the cathode on opening, which is equally powerful and sometimes stronger than the effect on opening at the anode.

The form of muscular contraction produced by *direct muscular stimulation* differs considerably from the contraction caused by the stimulation of healthy nerves. The latter is rapid, while the former is sluggish; and even if the current used be comparatively feeble, tonic contractions of long duration may be caused. The shortening and elongating of the paralysed muscle occurs more slowly than that of the healthy muscle, and corresponds to the form of contraction observed by Fick in the sphincter of the fresh-water mussel, in which there is considerable prolongation of all the successive stages of the contraction.

After a time galvanic excitability again diminishes, but no alterations then occur in its quality. The first signs of diminution occur about three months after the commencement of the disease. Within the following weeks the sign becomes more distinct; a higher power is required for causing contractions, and the latter are barely perceptible. The effect on opening becomes less, and appears more tardily than that on closing, even at the anode. This latter, however, still causes an equally distinct closing contraction at the cathode. At a later time feeble contractions are obtained by direct muscular faradisation, more especially in those muscles the nerves of which have regained their faradic excitability. Galvanic excitability now sinks below the normal standard; for while on the healthy side eight cells may suffice to cause contractions, from ten to fourteen cells may be necessary on

the paralysed side, and the contractions themselves become continually weaker.

These final alterations of electric excitability do not seem to bear any constant relation to the return of voluntary motor power, nor to the extent in which recovery takes place. At this time the muscles answer more readily to mechanical stimulation than they do in health.

Professor Erb has likewise studied the morbid anatomy of these conditions, and found that within the first few days after an injury to the nerve the marrow coagulates, and is dissolved into several cylindrical pieces, which are at first rather long, but afterwards become shorter. At the same time the diameter of the fibres is increased; the cylindrical pieces just mentioned are gradually changed into irregular oil-globules, between which fine granules of fat appear, which at last become so numerous that they predominate over all other formations. About the third week, and afterwards, there is less of marrow and fat, the diameter of the fibres becomes smaller, the structures more distinct, and nuclei and fibres in the process of regeneration are perceptible. Of the original fibres scarcely anything remains excepting a small and pale band with irregular outline, in some parts of which small globules of fat, marrow, and nuclei may be recognised. This band consists of the original primitive fibre and the cylinder axis, which remains uninjured. The degeneration proceeds in every case from the point where the injury has occurred towards the periphery; and regeneration follows the same course. From the substance of the marrow which has been preserved fresh masses of marrow are deposited round the cylinder axis. At first only a small dark line is perceptible; but after a time a delicate layer, with a double outline, appears, which proceeds more and more towards the periphery. These young regenerated fibres are very small, thoroughly homogeneous, and only slowly in-

crease in width. When they have become completely developed the conductivity of the nerve is restored.

At the point where the nerve has been injured, phenomena of adhesive inflammation of the neurilemma set in, viz. swelling, prolifereration of cells, thickening, and finally shrinking, of connective tissue.

The same occurs in the neurilemma along the whole peripheral course of the nerve. Soon after the occurrence of the injury, there is a considerable accumulation of granular cells in the neurilemma; these cells gradually assume the shape of spindles, and the neurilemma is thickened; the connective tissue becomes tougher and firmer, the cells disappear, and fibres take their place. The nervous fibres being now enclosed in a firm sheath, which becomes gradually harder by cicatricial shrinking, the recovery of the nerves is much retarded; but in course of time this impediment is likewise removed, and the nerves are at last completely restored to their physiological condition.

The anatomical alterations just described correspond closely to the changes of electric excitability which occur under these circumstances. The decrease of excitability, which occurs soon after the commencement of the paralysis, coincides with the progressing degeneration of the nervous marrow; and when this degeneration has reached a certain stage, the electric excitability is entirely gone. When, however, the fibres have become regenerated, electric excitability returns, and increases in proportion as the fibres grow. The slow return of excitability, and its long persistence in a low degree appears to be due to the impediment offered to the regeneration of the fibres by the proliferated and shrinking neurilemma.

The anatomical alterations of the *muscular fibres* commence in the third week. The fibres waste, and the transverse stripes become indistinct. There is no fatty degene-

ration, but an increase of nuclei, which often appear in large crowds; and the fibres show a great tendency to undergo amyloid degeneration. Large numbers of cells appear in the interstitial connective tissue, the bulk of which is increased, so that the consistency of the muscle is greater. The connective tissue after a time assumes a cicatricial character, whereby, after the conductivity of the nerves has been restored, complete recovery of the muscular fibres is much impeded.

It is more difficult to trace the relation between these anatomical alterations of the muscles and the changes of their electric excitability than it is with regard to the nerves. As during the first two weeks no striking alterations appear to take place in the muscular fibres, it may be assumed that the first changes of excitability in them are to be referred rather to the intra-muscular branches of the nerves and their terminations than to the muscular tissue itself. Concurrently with the diminution of excitability, which is caused by the separation of the nerve from the centre, muscular excitability is diminished; but it does not completely disappear because the contractile fibre with its inherent irritability is still in existence. Alterations of excitability commence towards the end of the second week; there is diminished effect of currents of instantaneous duration, increased effect of currents of long duration, and preponderating effect of the anode. These coincide, as regards time, with the commencement and increase of the proliferation of muscular nuclei, and those changes which result in amyloid degeneration and the proliferation of interstitial connective tissue.

The diminution of excitability which appears at a later time coincides with the cessation of these anatomical processes, and the atrophy of the muscular fibres, which is rendered more or less permanent in consequence of the cicatricial retraction of the hypertrophied connective tissue.

These phenomena are of importance for the diagnosis of palsies in which such alterations of excitability are observed. They show us with certainty that the paralysing lesion has interrupted the conductivity of the nerve, and that the latter is in a process of degeneration. The seat of the paralysing lesion is at the same time made known to the intelligent observer, inasmuch as these phenomena occur only in the motor and vaso-motor peripheral nerves, and not in central paralysis.

The prognosis of peripheral palsies depends therefore essentially upon their cause, and is more favourable where this can be rapidly removed. Before that is done, any therapeutical measures peripherally applied to the paralysed nerves and muscles must fail. In cases of facial palsy of this kind, a few months must elapse before the first traces of motility reappear, and even then a good deal of time is required for the complete restoration of voluntary power. Recovery is often incomplete, and distortion of the face, or at least a certain stiffness and rigidity, may remain for good.

Professor Erb's investigations have been confirmed by a series of researches made by Professor Ziemssen and M. Weiss,[1] who experimented on rabbits, in order to determine the galvanic and faradic relations of motor nerves and muscles in artificially produced interruption of nervous conduction. They operated on the sciatic and on the peroneal nerve, either by excision of a small piece or by ligature. The latter proceeding they found on the whole preferable, because it was possible, by a more or less tight tying of the thread, to produce palsies of longer or shorter duration, and also because the injury thus made generally healed by first intention.

The immediate consequence of the operation in all cases was paralysis of the whole set of muscles animated by the injured nerve, which continued for a time proportionate to the severity of the lesion. The average was four weeks with the ligature, but after excision of a piece of the nerve the palsy lasted six

[1] Deutsches Archiv für klinische Medicin, 1868. Bd. iv. p. 579.

months, and even longer. Considerable wasting of the leg followed, even when it had only been a few weeks paralysed. Where it remained so for six months, the wasting was not only great, but the muscles became rigid and shortened, so that the knee and ankle-joint were contracted. When the injury had been repaired, the contraction and rigidity of the muscles disappeared rapidly, the muscles increased in bulk, and voluntary movements returned.

The alterations of galvanic and faradic excitability of the injured nerve and the paralysed muscle were found to vary according to the severity of the lesion, but appeared to follow a definite law as regards their first appearance and progress. Ziemssen and Weiss corroborate Erb's discovery, that the relations of the *nerve* to electricity are totally different from those of the *muscle* to the same agent.

In most cases it was seen that, from twenty-four to forty-eight hours after the operation, the nerve had completely lost its excitability to the electric stimulus. Excitability was sometimes apparently increased on the first or second day; this, however, was not due to any changes in the nerve itself, but to an increased electric conductivity of the skin, consequent upon the operation. The minimum duration of the loss of excitability was three weeks, and the maximum seven months. The central end of the nerve regained its excitability some days, or even weeks, before its peripheral end. Galvanic excitability generally returned a few days before the faradic, in the central as well as in the peripheral extremity. The degree of galvanic and faradic excitability was always greater in the central than in the peripheral end; and the return of excitability in the nerve appeared to be simultaneous with the return of farado-muscular contractility, and the disappearance of exalted galvano-muscular excitability.

With regard to the *muscles* paralysed by the operation, it appeared that *faradic* excitability was diminished as early as the first day, and completely gone on the fifth to the nineteenth day after the operation. This diminution took place more gradually the nearer to the centre the injury had been made. Where the injury had been severe, farado-muscular excitability disappeared completely, and the paralysis continued for a longer time; and when traces of it reappeared, a very powerful current was at first necessary to show that it was returning.

Galvano-muscular excitability remained unchanged on the first

day, but was increased on the second, so that a feeble continuous current, which had no effect on healthy muscles, caused powerful contractions in the paralysed ones. This exaltation of excitability again decreased in the third to seventh week after the operation, and then fell either to the normal average, or even below it. In a few cases no such exaltation was perceptible, but these occurred in animals which had before the operation been uncommonly sensitive to the galvanic stimulus. In the large majority of cases galvano-muscular excitability persisted throughout the affection; it was lost only in those where a large piece of the nerve had been excised; and in these cases galvanic and faradic excitability fell much in the same proportion. With regard to the direction of the current, it appeared that the cathode, which in healthy muscles has more effect than the anode, had in these cases, on the contrary, less influence than the anode, which latter was by far the most effective.

The loss of muscular contractility in peripheral paralysis is in many instances a valuable guide to diagnosis. Duchenne has recorded a case in which he noticed loss of contractility in the paralysed muscles of the shoulder, by which he was led to the diagnosis of local injury to the nerves; and afterwards a syphilitic exostosis was discovered, which compressed certain branches of the cervical and brachial plexus. In most instances the faradic excitability of the muscles appears to be lost soon after the lesion of the nerve has occurred.

3.—PARALYSIS FROM DISEASE OF THE ANTERO-LATERAL COLUMNS OF THE SPINAL CORD.

In cases of this kind the electro-muscular contractility is either diminished or gone, according to the degree of severity of the affection. This constitutes in certain cases a good test for distinguishing between disease of the antero-lateral and posterior columns of the cord. In progressive locomotor ataxy, which affects chiefly the posterior columns,

the muscular response is generally quite normal, although the bulk of the muscles may have notably decreased, and they may refuse to obey the orders of volition.

4.—HYSTERICAL PARALYSIS.

Hysterical women often suffer from more or less complete paralysis of one or both lower extremities, which is usually caused by severe mental emotion and shock. Duchenne has found the electric excitability of the muscles normal in all cases of hysterical paralysis, while the electro-muscular sensibility (that is, the sensation excited by the electro-muscular contraction) was nearly or totally gone. Such is, however, by no means always the case, for I have seen cases of hysterical paralysis of long standing in which the excitability of the muscles was considerably diminished.

CASE 4.—*Hysterical Paraplegia; diminished excitability of the muscles.*

In May 1858, I saw, in consultation with Dr. Todd, a lady, aged 28, unmarried, who had nearly lost the use of her legs in consequence of a fright. Her gait was staggering, and when not sufficiently supported the limbs gave way, and she fell to the ground. The disease migrated about the limbs, sometimes attacking the right, and at other times more the left leg; for a short time the right hand became affected, and writing and playing on the piano were difficult or impossible. When I first saw her she dragged the right leg as a piece of inanimate matter; the foot swept the ground, and being inclined to turn inside, the inner edge of the shoe was torn after it had been worn for a few days. When in the sitting posture, she was hardly able to raise the foot or to turn it outside, or to move the toes; she experienced great difficulty in getting up from a chair, and in getting into and out of bed; and she found it almost impossible to press the pedals of the piano and the harp. On administering a feeble faradic current to the rectus of the *left* thigh, the muscle at once contracted, but the same current was not strong enough

to move the rectus of the *right* thigh. On increasing the intensity of the current, which sent the sensation of a powerful thrill through the thigh, only feeble vibrations appeared in the fibres of the left rectus. The same state was observed in the peronei and tibiales muscles: but after faradisation had been used for some weeks, the nutrition was so far restored that all the muscles of the right limb responded as readily to the current as those of the left.

5.—LEAD-PALSY.

Paralysis consequent on lead-poisoning affects with preference certain sets of muscles, leaving others nearly or totally intact. The arms and hands suffer, but the lower extremities do not; and in the arm the flexor muscles are spared and the extensors attacked. The extensor communis digitorum is first affected; the extensors of the first and the little finger follow in their turn; and at last the extensores carpi radialis and ulnaris, the triceps, and deltoid, and the muscles of the ball of the thumb, begin to suffer. In cases of this kind faradic excitability of the muscles is always much diminished, and often entirely lost, not only where atrophy has come on, but also where the bulk of the muscles is only slightly diminished; and sometimes the excitability of the muscles remains impaired even after the voluntary movements have regained their previous strength.

CASE 5.—*Lead-palsy; excitability of the muscles gone.*

S. R., a painter, aged 28, has had several attacks of lead-colics, from which he recovered under medical treatment. Six weeks before I saw him (August 1857) he had pain in the joints and twitches in the legs. The left wrist drops now, and he complains of obstinate constipation. A blue line was seen on the gums. All the extensor muscles of the left fore-arm, as well as the deltoid, were paralysed; and the patient could only raise his fingers if the first phalanges were supported, showing that the interossei and lumbrical muscles had not suffered. The

back of the fore-arm appeared hollow from atrophy of the extensors. He found it difficult to raise the arm, and impossible to extend it to a right angle with the body. The flexor muscles were not affected. The right arm was weak, but not paralysed. The lower extremities did not suffer. On applying a somewhat powerful faradic current to the deltoid muscle, slight vibrations appeared in its fibres, and no contractions could be produced in the extensor muscles on the back of the fore-arm. Faradisation was used every other day for about four weeks, after which the patient had recovered a considerable degree of power in the muscles, the bulk of which had much increased; but even then the excitability of the extensors of the left arm was much less than in those of the right.

The diagnosis between cases of lead-palsy and other kinds of paralysis has not only a theoretical but also a practical interest, as in the former the application of electricity must be combined with a constitutional treatment, while some other forms of palsy yield rapidly to galvanism alone. The mere statement of a patient that he has never to his knowledge been exposed to the influence of lead, does not prove that the paralysis is not of a saturnine character, for lead is often introduced into the system without the patient being aware of it. Nor is the paralysis of the extensor muscles always preceded by, or co-existent with, symptoms which belong to the constitutional disease, and which would, if present, facilitate the diagnosis. The electric response of the muscles is therefore a most valuable auxiliary for diagnosis, as it will in many cases enable us to recognise with certainty whether there is lead or no lead in the system.

Meyer[1] has recorded a very instructive case, in which he recognised by faradisation that the patient suffered from lead-poisoning. A hatter, aged 38, had for five months suffered from stiffness and weakness in both hands, which rendered him unable to use them. No further symptoms were or had been present previously. Meyer examined the muscles faradically, and found

[1] Loc. cit. p. 172.

that the extensor digitorum communis muscle did not respond to a powerful current, and that only a slight electro-muscular sensation was caused in it, while the other muscles of the arm responded well to faradisation. He therefore suspected the existence of lead-poisoning, although the occupation of the patient was not one in which lead is used, and although there were no other symptoms pointing to the presence of that metal in the system. Faradisation was resorted to, but thirty-seven applications had no beneficial effect. Two months later the patient was worse, and he then mentioned, in reply to enquiries about lead, that he had for many years past used snuff packed in lead-foil. The analysis of this snuff showed the presence of a considerable quantity of lead in it. The use of the snuff was now prohibited, and sulphur baths and saline purgatives administered for four weeks. The palsy was then again attacked by faradisation, and the patient ultimately recovered.

6.—RHEUMATIC PARALYSIS.

Duchenne has found that in this form of palsy the electro-muscular contractility is normal, while the sensation excited by the electro-muscular contraction may be stronger in the suffering side than in the healthy parts. This is true for recent cases; but in such of long standing I have almost invariably found farado-muscular excitability impaired.

7.—PROGRESSIVE MUSCULAR ATROPHY.

In this disease the farado-muscular contractility corresponds to the more or less wasted condition of the fibres. The more the bulk of the muscle is diminished, the weaker is the contraction exhibited by it. Electricity enables us in most cases to ascertain the state of almost every muscle and portion of a muscle, whether normal or wasted. I have seen cases in which not the whole substance of the extensor communis digitorum was atrophied, but merely that portion

which extends the middle finger. This was distinguished by placing the electrodes of an induction apparatus upon that muscle, when only the first, the fourth, and the little finger were extended, while the second finger remained quite or nearly motionless. The same may be observed if the current is directed to the interossei and lumbrical muscles, when only one or two of them may respond, while the others are not affected even by a powerful current.

II.—THE USE OF ELECTRICITY IN DETECTING MALINGERERS.

Malingering for the purpose of extortion, for procuring the means of subsistence without work, or for exciting compassion and interest, is much more frequent than is generally supposed. Where the physician's suspicions are aroused, faradisation of the skin by the wire-brush (electric fustigation, p. 417) may be an excellent means of settling such questions. This proceeding is extremely painful, and yet never does any harm, except in cases of cerebral disease, where it should be avoided. We need, therefore, not be reluctant to employ it in suspicious cases, as it is far more humane than the actual cautery (which has often been called in requisition), and yet sufficiently disagreeable to make a repetition of the procedure dreaded by such persons. The Welsh fasting-girl might still be alive and in the enjoyment of a hearty appetite, if her case had been looked upon in a proper light, and if faradisation of the skin had been a few times employed as a diagnostic and curative measure.

Faradisation may also be usefully employed where certain forms of paralysis are assumed by malingerers. The following is an instance of this :—

CASE 6.—*Malingering detected by faradisation and the use of nitrous oxide gas.*

In November 1871 I was consulted by the secretary of a working-men's benefit society with regard to the case of one of the society's members, who professed to have lost the use of his left arm in consequence of an accident which he had had three years previously. According to the society's rules, the sum of 100*l.* is paid to members who are permanently incapacitated for work by disease or accident. The patient had had a fall from a considerable height, and asserted that ever since he had been unable to use his arm. He had been admitted into a provincial hospital, where he remained for three months, and where (to use his own words) 'the surgeon tried as hard as he could to cure him,' but failed. In course of time the man, who was known not to have done any work since the occurrence of the accident, applied to his society for the 100*l.* owing to him; and I was then requested to give an opinion whether the patient was permanently or only temporarily disabled.

The claimant was a tall, powerful man, of determined countenance, and evidently considerable force of will. He professed to be unable to undress himself, and had therefore to be assisted when the helpless limb was bared for examination. I found that the temperature and the bulk of the left arm were in all its parts quite equal to those of the right. The limb was held in full extension, and drawn to the body, while the fingers were somewhat tightly flexed. On endeavouring to flex the fore-arm and to supinate the hand, considerable resistance was encountered; and, when additional force was used for effecting this purpose, the patient called out with pain, and said he could not bear the manipulation.

Seeing this condition of the limb, only three pathological conditions could be suspected, viz. paralysis with contraction, ankylosis, or dislocation—provided always that the patient was sincere. In peripheral paralysis, owing to injury of the motor nerves of the part—which is the only form of paralysis that could be thought of in this case—there is rarely any great amount of contraction, since the paralysed limbs are mostly found flabby; and, if the case be of long standing, the muscles are wasted, and the temperature is considerably diminished. But

as these clinical signs, although of value, are yet not invariably present, I employed a test which gives absolutely decisive results in such cases, and enables us at a glance to decide the presence or absence of peripheral paralysis—viz. faradisation. It has been shown by the concurrent testimony of all recent observers who have investigated this subject, that, in peripheral paralysis caused by injury to the motor nerves, the muscles animated by those nerves lose their *faradic* excitability, while their *galvanic* excitability may be preserved, or, under certain circumstances, even increased. If, therefore, in the present case, the deltoid, triceps, biceps, and the other muscles of the useless limb, could be made to respond by contraction to the faradic current, it would be rendered evident that there was no paralysis owing to injury of the brachial plexus or any of its branches.

On using faradisation, I found that all the muscles of the arm and hand responded readily to the current by contraction of their fibres ; yet, curiously enough, the arm of the patient did not execute those movements which are generally produced by such an application. Something evidently resisted the displacement of the bones ; and when I looked at the powerful determination visibly expressed in every feature of the patient's face, his hard stare, his contracted brow and lips, I could not help feeling suspicious that this something might be the patient's own volition. The influence of faradisation being irresistible if a sufficiently strong current be used, I increased the power with which I acted, in order to overcome any possible resistance on the part of the patient; but the latter called out so lustily, saying that he could not bear the pain, that I was obliged to desist. Enough, however, had been ascertained for enabling me to eliminate one of the three pathological conditions which could give rise to the complaint of the patient.

I now informed the secretary that, although I had satisfied myself that there was no paralysis, yet it was impossible for me to give a certificate concerning the exact nature of the affection from which the patient suffered, unless he were previously placed under the influence of an anæsthetic. All parties having consented that this should be done, I procured the assistance of Mr. Clover, who on the following day administered nitrous oxide gas to the patient. The latter was rapidly rendered insensible ; and I could now freely move the arm in all directions, there being neither dislocation nor ankylosis. As soon as this was ascer-

tained, the influence of the anæsthetic was withdrawn; and the patient, who recovered himself in a few moments, was informed that his case was not nearly so bad as he had imagined, and that he would certainly recover the use of the arm under proper treatment. I gave a certificate to the effect that the patient suffered from a painful affection of the shoulder-joint, which would yield rapidly to subcutaneous injections of morphia or a judicious use of galvanism; and that there was neither paralysis, nor dislocation, nor ankylosis, seriously to interfere with the use of the extremity. The claim was therefore not allowed.

III.—THE USE OF ELECTRICITY FOR THE DISCOVERY OF PROJECTILES LODGED IN THE BODY.

It is often of great importance to the surgeon who has to treat gunshot wounds, to decide with certainty whether a solid body which is felt in the depth of the canal is a piece of bone or a bullet. Again, in the later stages of gunshot wounds, after the openings have healed, doubtful swellings not unfrequently become perceptible in the neighbourhood of bones, and which may be owing to fragments of bullets or not. The various methods which are now in use for examining such cases have been described with admirable lucidity by Professor Longmore,[1] of Netley; and one of these methods is that by the galvanic test.

We have seen in the first chapter that the human body is an infinitely worse conductor of electricity than the metals. Amongst the metals lead does not rank very high in conductivity; for it conducts much worse than silver, copper, gold, iron, or platinum. Nevertheless, it conducts several million times better than muscular tissue or bone; and the galvanic current will, therefore, without difficulty, indicate the presence of a piece of lead, which may be imbedded in

[1] British Medical Journal, vol. ii. 1871, p. 715.

the soft parts or bones, by a deflection of the magnetic needle on closing the metallic circuit; while the needle will remain motionless, if bone or muscle be placed in the circuit instead of the lead.

The merit of having first utilised the action of the galvanic current for the discovery of projectiles is due to Professor Favre,[1] of Marseilles. He found that if he introduced the two conducting wires of a single galvanic pair into a wound, and connected one of the wires with a galvanometer, the contact of the tissues and liquids in the wound was not sufficient for establishing the current; but on arriving at a metallic body the needle was deflected, showing that the circuit of the battery had been closed. A French army surgeon, M. Fontan, on hearing of this experiment, repeated it in the military hospital of Marseilles. He used one pair of Smee's battery, an ordinary galvanoscope, and two metallic probes, one of which was covered by the other. The internal one of these carried two insulated conducting wires ending in steel points, while the external one was wide enough to receive the inner one, and having two fenestrae in order to let the steel points of the conducting wires be pushed forward to the object that was to be explored. M. Fontan found that if the conducting wires ended in blunt points, the result was either *nil* or at least not so striking as when sharp steel points were employed, which penetrated more easily to the surface of the projectile.

Prof. Rosenthal,[2] of Vienna, says that the galvanic test was used by Nélaton in Garibaldi's case, and that the presence of the bullet in the tarsal bones of the Italian patriot was shown by the deflection of the magnetic needle. This statement, however, is incorrect. The real facts of the case, about which, considering its recent occur-

[1] Gazette des Hôpitaux, 1862, p. 553.
[2] Die Electrotherapie. Wien, 1873, p. 381.

rence, a most extraordinary diversity of impression prevails, are these :—Nélaton satisfied himself, by the usual examination of the wound, that a bullet was present ; but as Prof. Partridge had, previous to this, denied the existence of a foreign body, and as Nélaton himself did not convince the Italian surgeon who was in attendance on Garibaldi, of the correctness of his view, the French professor, on his return to Paris, thought of improving the methods then in use of probing for bullets. He therefore consulted M. Em. Rousseau, the chemist, with the view of finding a chemical test by means of which the presence of lead in the depth of a wound could be ascertained. M. Rousseau then recommended to introduce a small piece of unglazed 'biscuit' china, on which lead would make a mark that could not be obliterated by any liquids or solids present in the wound. Upon this hint Nélaton and Charrière constructed the 'porcelain probe'—that is, a slender rod of metal, five or six inches long, and terminated by a small knob of porcelain, the mere friction of which on lead was found to be sufficient to make a mark that was indelible by the soft parts or the morbid secretions of a wound. Such an instrument was sent out to Prof. Zanetti, of Pisa, who examined Garibaldi's wound with it, perceived the lead mark, thus corroborated Nélaton's opinion, and extracted the bullet on November 23, 1862.

A civil engineer, Mr. De Wilde,[1] appears to have been the first who proposed using the electric bell for the purpose of showing the presence of a bullet in a wound. He has constructed a galvanic pair connected with a multiplier, and an exploring probe. When the circuit is closed, the galvanic current causes a hammer to strike against an alarum bell; and this is repeated when the circuit is opened. M. Kovacs, of Pesth, and Prof. Neudörfer, have constructed similar in-

[1] The Lancet, August 10, 1872.

struments; and Messrs. Krohne and Sesemann have manufactured one in which the deflection of the magnetic needle indicates the presence of the metal. One of the simplest contrivances of this kind appears to be that described by Dr. Oscar Liebreich,[1] of Berlin.

In this there is a single galvanic pair of copper and zinc, which may be charged by putting a piece of blotting-paper, moistened with salt-water, over it; and both the galvanic pair and the galvanoscope are compressed into the smallest possible space. The probe ends in a pear-shaped knob; the wires run in an insulating sheath of india-rubber and end in metallic plates, which are insulated from one another by a cone of ivory. If the diagnosis has to be made by puncture, ordinary glovers, or sewing-needles, may be connected with the conducting wires. When the probe is used, it is of course necessary to see that the ends of the conducting wires should not touch one another outside the wound. Prof. Esmarch and Dr. Hoffmann have used this probe in a doubtful case of gunshot wound, and were by means of it enabled to distinguish, that of three swellings under the skin of the knee in a private soldier who had been wounded before Metz, two were owing to fragments of a bullet, while another was bone. The fragments were readily extracted, and proved the correctness of the diagnosis.

IV.—USE OF ELECTRICITY FOR ASCERTAINING DEATH.

The thought of being buried alive is probably the most repulsive one which may present itself to the human mind. Numbers of persons have, when feeling the approach of death, requested a post-mortem examination to be held in their cases, evidently preferring dissection to interment

[1] Berliner klinische Wochenschrift, Oct. 23, 1870.

while still alive. No reasonable doubt can be entertained that vast numbers of men have, in past times, been buried alive, more especially during epidemics and after great battles; but also, in isolated instances, after poisoning, drowning, lethargy, etc. Rachel, the celebrated French actress, had been eleven hours in her coffin when she awoke from her trance, and lived for some hours afterwards. Dr. Josat states that in France about thirty or forty people are annually buried alive. On February 27, 1866, a debate on this subject took place in the French senate. M. de la Gueronnière said that, to his knowledge, when graves had been removed in old burial-places, 'skeletons had been found in their coffins in all sorts of positions. Their limbs, horribly distorted, betrayed the last revolt of life, the agony of a terrible situation, of which the living had heard neither a cry nor even the last sigh!' Cardinal Donnet narrated that he had saved two people from being buried alive, and that such an accident very nearly occurred to himself:—

In 1826, a young priest, while standing in the pulpit, suddenly fell down, and was pronounced to be dead by the doctor who examined him. He heard the funeral chant, the *De Profundis* recited at his bedside, and all preparations for his burial, without being able to move or to pronounce a single word. A providential accident allowed him to come out of his trance in time. To-day, having become the Cardinal Donnet, he requests the powers that be not only to take care that the legal forms concerning burials should be strictly observed, but also to introduce new tests, in order to prevent irreparable disasters.

The signs of death which are most generally relied upon are, cessation of the heart's action and of respiration, a considerable fall of temperature, rigor mortis, the dull cornea, the dilated pupil, non-transparency of the fingers to candle-light; and finally, decomposition. All of these signs, however, are occasionally of doubtful value.

a. *Cessation of the heart's action and of respiration*, as evidenced by auscultation, may, in certain cases, be deceptive. In the first instance, even a slight degree of deafness in the practitioner who is in attendance may prevent faint sounds from being perceived by him; and secondly, cases are on record in which experienced physicians and surgeons have failed to observe any of the ordinary phenomena of auscultation in persons who were only apparently dead, and who afterwards recovered.[1]

b. *Decrease of temperature* is no certain sign of death. In some cases there is even a post-mortem *increase* of temperature; and in hot weather the fall of temperature is very slow. On the other hand, the temperature may be as low as 81·3°, and life yet be extant.[2]

c. *Muscular rigidity* is likewise not an infallible sign of death, because it may occur during life in tetanus, strychnia, poisoning, and catalepsy; and it fails to show itself at all in certain other forms of poisoning.

d. The *dull cornea* occurs in severe cases of fever, and in some cerebral affections during life, while it is absent in certain forms of poisoning.

e. The *dilated pupil* is observed in not a few cases of amaurosis and brain disease during life.

f. *Non-transparency* of the fingers by candle-light may be absent in persons who have died from cholera and consumption; while in patients who have during life suffered from dropsy, the fingers may still be transparent one or two days after death.

g. *Decomposition* is an unquestionable sign of death; but is often exceedingly slow to show itself, more especially in cases of poisoning, in habitual drunkards, and in persons who have died of diseases accompanied with wasting.

[1] Vide Von Hasselt, Die Lehre vom Tode und Scheintode. Leipzig, 1862. Bourneville, in Gazette des Hôpitaux, No. 5, 1872.

None of these signs are as ready and as decisive as faradisation, which indicates death with absolute certainty, within two or three hours after its occurrence.

The application of galvanism for distinguishing real from apparent death, or trance, was recommended as early as 1792 by two German physicians, Drs. Behrend and Creve;[1] and the anatomist Sœmmering proposed to apply the 'metallic stimulus' in such cases to the phrenic nerve. In this country Fothergill[2] endorsed that recommendation; and Heidmann,[3] of Vienna, followed in his wake. Boer, Professor of the Obstetric Institute of Vienna, successfully used static electricity for the purpose of deciding between life and death of newly-born infants, and found that if muscular contractions were caused, the child was not dead, and could generally be roused to life by the application. On the other hand, if no contractions were observed, even the most zealous use of the most effective means of resuscitation failed.

That faradism is the readiest and most useful form of electricity for ascertaining that death has taken place, was first pointed out by Dr. Crimotel,[4] of Paris, who, in 1852, submitted a memoir to that effect to the Conseil de Salubrité de la Seine, and stated that electro-muscular contractility continues in health as well as in disease, and also in lethargy, apoplexy, syncope, and all kinds of asphyxia or poisoning, as long as life is extant; but that when faradic contractility is gone, we may say with certainty that death has taken place. This property is not extinguished immediately after death, but its perceptible and gradual diminution from that instant shows that only a feeble remainder of vitality is left, which rapidly becomes less and

[1] De metallorum irritamento veram ad explorandam mortem. 1793.
[2] A New Enquiry into the Suspension of Vital Action. Bath, 1795.
[3] Zuverlässige Prüfungsmittel, etc. Wien, 1804.
[4] De l'Épreuve galvanique, ou Bioscopie électrique. Paris, 1866.

less as time goes on; and, after an interval—which varies according to circumstances, from half an hour to two hours and a few minutes, but never as much as three hours—it disappears altogether. 'Electro-bioscopy,' therefore, according to him, not only prevents the terrible misfortune of burying a man who is still alive, but it may also encourage us to persevere with our efforts for restoring life in people who are apparently dead from lethargy, apoplexy, syncope, drowning, freezing, the inhalation of chloroform, poisoning by charcoal fumes, etc.; while it, finally, proves to be one of the most effective means of restoration from apparent death.

M. Crimotel recommends for this purpose a small faradic pocket apparatus, constructed by Morin, of Paris, with a sulphate of mercury battery, which can be put into and out of action in a minute, and yields a sufficiently powerful current for rendering the test decisive.

After having experimented upon a number of cases of apparent death in animals and men, and also upon deceased persons of all ages, and who had died of the most varied complaints, M. Crimotel has arrived at the following conclusions:—

1. Death is certain when the muscles have entirely lost their faradic contractility; on the contrary, life is probably extant when this property is preserved in its full integrity. A perceptible diminution of it is a sign that life has ceased a short time ago. In newly-born infants he has found the contractility to continue from fifteen to sixty minutes after the heart had ceased to beat, but it was diminishing progressively all that time. In children and adults the contractility persists longer than in infants, and the length of its post-mortem continuance varies according to the nature of the disease and the kind of death; but it never continues as long as three hours after death. In some cases of cholera it was found to be entirely gone half an hour after life had become extinct; the same was observed after more or less prolonged diseases which had gradually exhausted the vital forces, such as phthisis, typhoid fever, etc. In all cases, how-

ever, in which faradic contractility had been unimpaired up to the last moment of life, it was seen to become perceptibly modified soon after the heart had ceased to beat. The most powerful current did then no longer produce those strong movements of flexion and extension which were caused during life ; on the contrary, the movements were limited, the contractions enfeebled, and at last only slight vibrations could be observed, which were in their turn followed by complete absence of any response whatever.

2. No disease, nor any kind of asphyxia or poisoning, will during life abolish the faradic contractility *in all the muscles* of the body. Majendie and Royer have shown that in dogs, poisoned by carbonic oxide and sulphuretted hydrogen, the contractility persisted for some time after death. Claude Bernard has found the same to be the case with woorali, strychnia, and other poisons. It is true that in certain forms of paralysis faradic contractility may be lost, but such forms of paralysis never affect all the muscles of the body. In muscular atrophy, with or without fatty degeneration, farado-puncture would produce contractions, and the diaphragm would respond to faradisation of the phrenic nerve.

3. A notable diminution of faradic contractility in the whole muscular system is a sign of death. In apparent death, on the contrary, it is sometimes augmented. If in about twenty minutes after the occurrence of apparent death no diminution occurs, life is probably still extant.

4. 'Electro-bioscopy' should be recommended in all doubtful cases, and anyhow where the relations of the deceased should desire it to be employed ; it being a radical means for preventing premature interment.

5. The faradic test becomes indispensable in the drowned, the asphyxiated, &c., and should be imperatively required of those practitioners who have to certify in cases of sudden death. When there are several victims—as from shipwreck, railway accidents, &c.—it would have the additional advantage of enabling the attendants to distinguish at once the dead from the living. The doctors would therefore be in a position not to lose precious time with the dead, but might concentrate their attention on those who would still be benefited by it.

(After great battles, the faradic test would probably prevent many a premature burial).

In newly-born infants, again, who do not give signs of life, 'electro-bioscopy' would be of the utmost value.

6. The faradic test will allow the practitioner to certify, if a remainder of contractility be still discovered, that death has taken place within three hours of the observation.

7. When several persons have perished by the same accident, the test may permit, in certain cases, to decide in which order they have ceased to live.

8. In the hands of the practitioner the test becomes at the same time one of the most powerful, prompt, and effective means for resuscitating persons who have apparently ceased to live.

Finally, it may allow the authorities to accelerate the burial of the dead, or any operations to be performed with deceased persons; such as embalming, post-mortem examination, &c., in case it should be inconvenient to wait for the ordinary delay.

The French Code prescribes that no burial may take place until 24 hours after death; and as permission is only given 24 hours after declaration has been made, there is often a delay of 40 or 45 hours altogether. During epidemics, and amongst the poor, an earlier interment would often be advisable.

M. Crimotel has given some cases in which he has used the faradic test, and of which I have tabulated the following:—

Sex	Age	Disease	Time of extinction of faradic contractility after death
Female	38	Cholera	30 minutes
,,	14	Asphyxia by charcoal fumes	75 ,,
,,	38	,,	100 ,,
Male	2 years	,,	100 ,,
,,	3 months	,,	100 ,,
,,	31	Cerebral hæmorrhage, sudden death	90 ,,
,,	57	,,	110 ,,
,,	2½	Drowning	115 ,,
,,	54	Pulmonary congestion	118 ,,

Professor Rosenthal,[1] of Vienna, has more recently investigated the whole subject in a scientific manner. He followed the gradual extinction of both faradic and galvanic excita-

[1] Medicinische Jahrbücher, IV. Heft, 1872.

bility of the nerves and muscles after death in twenty cases, the patients having died from various diseases, such as pneumonia, apoplexy, fever, &c. His results agree, on the whole, with those of M. Crimotel. He found that the post-mortem electric excitability disappears more rapidly after death from chronic than from acute disease; that it remains longer in well-nourished than in wasted bodies, and that it is generally extinguished in from ninety minutes to three hours. In one case, when all traces of excitability, even to galvano- and farado- puncture by a most powerful current had disappeared, the temperature in the rectum was still 99·4°, and the joints were still quite flexible; yet death could be diagnosed with absolute certainty. In amputated limbs he found faradic as well as galvanic excitability well preserved during the first hour after the operation; ninety minutes afterwards only electro-puncture could show traces of it, and in two hours after no response whatever took place. In a case of drowning, a feeble faradic current produced good contractions within the first hour; after that it was necessary to increase the power of the current in order to cause contractions of the same strength as before. In two and a half hours, only the orbiculares of the eye and the mouth, and the flexors of the fore-arm, answered to the maximum power of the apparatus. In three hours and a quarter electric excitability had everywhere vanished. Rigor mortis only appeared after five hours in the hand, and after six hours in the elbow.

The same observer has recorded an interesting case of trance in a hysterical woman, in which a country practitioner had declared death to have ensued, as a looking-glass held to the mouth did not show any moisture, and melted sealing-wax dropped on the skin caused no reflex movements. Rosenthal, who was accidentally present, found the skin pale and cold, the pupils contracted and insensible to light, the upper and lower extremities relaxed, the heart's impulse and the radial pulse imperceptible. Auscultation, however, showed a feeble, dull, and

intermittent sound in the cardiac region. No respiratory murmurs were audible. All the muscles of the face and extremities responded well to the faradic current. Although the patient had been apparently dead for thirty-two hours, he thereupon informed the relations that it was only a trance, and recommended that attempts at resuscitation should be perseveringly followed. On the following day he received a telegram to say that the patient awoke spontaneously twelve hours afterwards, and gradually recovered her speech and movements. Four months afterwards the patient called upon him, and informed him that she knew nothing of the commencement of her attack of lethargy; that she had afterwards heard the people about her talk of her death, but had been utterly unable to give the slightest sign of life. Two years afterwards, she was still alive and tolerably well. Rosenthal appropriately likens this condition to that of 'nightmare,' where, in spite of distressing sensations, the dreamer is unable to call for help or to make any movements which might save him from some imaginary impending danger.

CHAPTER V.

ELECTRO-THERAPEUTICS.

The therapeutical sphere of the several forms of electricity has of late become so much enlarged, that those who have given no attention to the gradual progress of the subject will probably think the catalogue of diseases in which the use of electricity is now recommended too long, and object that a remedy which is employed for complaints of such very different character is not likely to do good in any. But it should be considered, in the first instance, that 'electricity' or 'galvanism' is not *one* single thing, but that there are *four* different forms of it, each of which possesses peculiarities of its own which distinguish it from its fellows; while from one of them, viz. the continuous current, many radically different effects may be obtained, according as we use its stimulating, electrotonic, electrolytic, or cauterising action. Then, again, it must not be lost sight of that modern pathology justly attributes a far more important influence to the vaso-motor and trophic systems of nerves in the production of disease than was done formerly, and that an agent which has been experimentally shown to possess constant and powerful effects on these systems of nerves is *à priori* not unlikely to be effective in diseases caused by a pathological condition of the same. An instance of this is to be found in Basedow's or Graves's disease, where the application of galvanism would appear *à priori* unreasonable, unless we were guided by the principle just enunciated. Finally, it

should be understood that I by no means wish to convey the idea that *all* diseases which are discussed in this chapter should be treated by some form of electricity. I am convinced that, in the large majority of cases which come under our care in the course of practice, there are three or four different ways of curing the patient; and it is the object of therapeutical science to find out the safest, quickest, and least unpleasant mode of doing so. This, however, can only be accomplished by comparing the results obtained from different modes of treatment, which will eventually lead us to adopt the best. In the following chapter it has been attempted to show what a scientific use of the various forms of electricity can accomplish for the alleviation or cure of disease; but it is by no means intended to urge its exclusive adoption in place of other remedies, which in some complaints may be equally, or perhaps even more, effective. Certain morbid conditions are only mentioned in order to state that, for the present at least, no beneficial effects can be expected in them from electricity. On the other hand, there are affections in which *nothing but electricity* can do real good, and for these its employment will be strongly urged; while, finally, there are some in which electricity may be resorted to, either after other modes of treatment have failed, or where physician and patient incline more to electricity than to physic, or to a mere dietetic and hygienic kind of treatment.

The precise mode in which electricity produces its therapeutical effects is still to a great extent shrouded in mystery; but much more is now known of it than was the case formerly.

A. *Static Electricity* is a powerful stimulant, especially for the sentient nerves, and may be used with benefit wherever it appears desirable to produce a profound modification of their condition. It appears to have greater effects in some

kinds of anæsthesia than any other form of electricity, and may likewise be used as a counter-irritant in headache and certain forms of neuralgia and spasm.

B. The effects of the *constant current* are much more complicated than those of static electricity, and in many instances do not as yet admit of a satisfactory explanation.

Remak [1] was the first to attempt such an explanation, and distinguished three principal effects of the current, viz. the catalytic, the anti-spasmodic, and the anti-paralytic. The first of these were, according to him, chiefly seen in inflammatory conditions and their consequences. He called them catalytic, because an analysis of his observations satisfied him that where the current removed a morbid condition of the tissues caused by defective circulation, or by effusions, this was not due to electrolysis, but to dilatation of the blood-vessels and lymphatics, whereby circulation and absorption were facilitated. The catalytic effects were of service in inflammatory conditions of the brain leading to tremor and spasm; in inflammation of the spinal cord, with consequent palsy of the lower extremities, bladder, and rectum; in chronic painful rheumatism of the joints, muscles, tendons, periosteum, nerves, and in certain spasmodic affections caused by local irritation; in inflammation of the joints caused by injury or rheumatism; in effusions, more especially in dropsy of the joints; and in painful and inflamed tumours. Concerning the mode of application, Remak was guided by the circumstance that a conveyance of liquids is effected between the two poles, and which proceeds in the direction from the positive to the negative (electric endosmosis, p. 45). He therefore advised to place the cathode to the inflamed part, and the anode somewhere in its neighbourhood; but as soon as symptoms of effusion were present, the

[1] Loc. cit. p. 203.

position of the electrodes should be reversed. Again, where the character of the inflammation was erethic the positive, and where it was torpid the negative, pole should be employed with preference near the seat of disease.

The *anti-spasmodic effects* of the continuous current were, according to the same observer, partly due to its increasing the power of volition over the muscles affected by spasm or tremor, and to its removing catalytically any irritation which might cause the spasm; and partly to a direct reduction of the exalted excitability of the nerves or muscles. These effects were chiefly seen in the treatment of reflectory spasms, such as blepharo-spasm and histrionic spasm; in the commencement of shaking palsy; in nystagmus; in scrivener's palsy, stammering, and chorea.

The *anti-paralytic effects* of the continuous current were seen chiefly in hemiplegia and paraplegia, provided the disease causing these affections had not too profoundly injured the nutrition and structure of the brain and cord; and also in anæsthesia, atrophy of the muscles, traumatic paralysis, and secondary paresis.

Remak's theories, although somewhat crude, nevertheless contain germs of truth which it would be foolish to ignore. The real difficulty which is experienced in explaining the therapeutical effects of the constant current lies in the fact that we at present know only little of the finer processes of disease of the nervous system; and the difficulty is therefore more of a pathological than of a therapeutical kind. The case of electricity in this respect is, for the same reason, by no means an isolated one; for nobody has as yet succeeded in explaining the exact manner in which strychnia, phosphorus, nitrate of silver, and other reputed nervine remedies, act in nervous diseases. Indeed, we may say that we have far more accurate notions concerning the effects of electricity than concerning the action in the system of the medicines which have

just been enumerated. Further researches bearing upon practical electro-therapeutics, as well as upon the pathology of the nervous system, will no doubt considerably modify our present ideas on the therapeutical action of electricity; and the following remarks must therefore be taken not as permanently settling the numerous questions under consideration, but simply as expressing the most advanced ideas of the day on these matters.

Pflüger's researches on electrotonus appear to us to supply the key to the large majority of the therapeutical applications of the constant current. We have seen (p. 210) that a continuous current which passes through a nerve, causes certain alterations of excitability in the same, viz. a zone of increased excitability in the neighbourhood of the cathode, and a zone of diminished excitability in the neighbourhood of the anode. Cyon has proved that Pflüger's researches, which were made on rheoscopic limbs, hold good for the nerves of the living man likewise; and the systematic *production of catelectrotonus and anelectrotonus*, for the purpose of increasing or diminishing the excitability of diseased portions of the nervous system, has thus been shown to be a therapeutical possibility. The polarising or electrotonic effects of the current may therefore be utilised in certain forms of paralysis and anæsthesia, where catelectrotonus should be produced, and in spasm and hyperæsthesia, where anelectrotonus finds its appropriate sphere of action. We have thus found a scientific explanation for Remak's 'antiparalytic' and 'antispasmodic' effects. With regard to the special mode of application, it may be laid down as a general principle that for the nervous centres the continuative application (p. 340) is, under all circumstances, the most appropriate, while for the peripheral nerves and muscles the continuative application should be combined in most cases with

an intermittent application, which produces particularly stimulating effects.

This brings us to a second point which we have to consider in the therapeutical applications of the current. We have seen in the second chapter that the *continuous current is a powerful stimulant for all the different portions of the nervous system*, and that these stimulating effects become more particularly developed where an intermittent application and voltaic alternatives are resorted to. Passes with the cathode, and voltaic alternatives in the metallic circuit, are therefore the necessary complement of catelectrotonus in cases where a powerfully stimulating effect upon certain portions of the nervous system is required.

The *refreshing* or *restorative* effects of the continuous current may likewise be utilised in a variety of pathological conditions, particularly in cases of exhaustion of the several parts of the nervous and muscular systems, in consequence of over-exertion. The inverse current is more effective in these cases than the direct.

The *electrolytic* action of the continuous current is unquestionably one of its most important properties. That such an action takes place during the percutaneous application of the current is not only *à priori* probable, but is also definitely proved by the peculiar effects of the anode and cathode on the unbroken skin (p. 265). It is at present not settled what peculiar kind of influence the electrolytic effects of the current, when percutaneously applied, exert in therapeutics, nor in what classes of cases they are practically useful; but a persevering study of this most difficult point will no doubt in course of time lead to scientific and practical results of the greatest importance.

These remarks apply likewise to the *endosmotic* effects of the current, which, although closely allied to the electrolytic action, yet are essentially different from the same.

Remak's *catalytic* effects of the constant current are those which are produced by direct stimulation of the vaso-motor nerves, which latter transmit the influence to the blood-vessels and lymphatics. In this way the processes of nutrition throughout the system may be influenced by galvanisation. It appears to us that for 'catalysis' we might substitute the more intelligible term of 'catelectrotonus.' By catelectrotonus of the vaso-motor nerves absorption is promoted, and effusions may thus be removed into the general circulation. Most probably the therapeutical effects of the current in rheumatism and rheumatic gout, in neuritis, in dropsy of the joints, &c., are owing to what may be called 'catalysis,' or better, '*catelectrotonus of the vaso-motor system of nerves.*' One of the best modes of utilising these effects of the current is to resort to the proceedings known as 'galvanisation of the cervical sympathetic nerve.'

We have already several times been compelled to allude to Brenner's so-called 'polar method of galvanisation,' and we have now to discuss the question whether this polar method has any secure physical or physiological foundation and practical usefulness. Brenner has denied the possibility of sending an electric current with certainty through the uninjured human body, and is of opinion that nothing is certain except the action of the two poles, which always remains the same; that the direction of the current is utterly devoid of influence; and that the intra-polar portion of the nerve must not be considered as traversed by the current.

Brenner's theory, which *primâ facie* seems to run counter to all the best established facts in electro-physiology and therapeutics, has, in spite of the remarkable ingenuity of its progenitor, not found any favour with electro-therapeutists generally; but a staunch champion for it has lately arisen in Professor Erb,[1] of Heidelberg. Erb considers that the

[1] Volckmann's Klinische Vorträge, No. 46, 1872.

effects of the poles are everything in therapeutics—first, because the effects of the direction of the current have not yet found a satisfactory explanation; secondly, because the stimulating, electrotonic, and electrolytic effects are simply polar; and finally, because most parts of the body may during life be brought under a sufficiently powerful polar action, while the parts cannot be brought under the influence of a special direction of the current on account of its too feeble density. These reasons appear to Erb sufficient to make him prefer the polar method to any other; but he at the same time confesses that that method lacks a secure scientific basis as long as our knowledge of the effects of the poles, and of the pathological alterations we have to treat by them, remains defective. He therefore considers it in most cases the best to trust simply to experience when we have to consider which pole to use in any special case. In neuralgia he would first try to induce anelectrotonus, or the condition of diminished excitability of the nerve; but he would not be surprised, nor find it in contradiction with polar principles generally, if in certain cases the production of catelectrotonus were to cure the neuralgia. It would then only be necessary to alter our ideas on the nature of such cases of neuralgia, and on the curative polar effects. On the other hand, Erb does not go so far as to recommend the use of the polar method in all cases; for, where the catalytic or trophic effects are to be utilised, he would prefer placing both poles to the diseased organ, so as to make the current pass through it as completely as possible: this would be the case with the brain, the joints, and the muscles; nevertheless, he thinks that even in these cases future researches will teach us a more suitable mode of polar application.

Dr. Burckhardt, of Basle, has made a series of experiments with the special object of testing the correctness of Brenner's theory, which have been carefully performed, and led to very

convincing results. The first question he endeavoured to determine was, whether it is possible or not *to send a continuous current in a certain direction through a nerve.* In a dead body, after rigor mortis had set in, the sciatic nerve was laid bare from the anterior surface of the thigh, its sheath opened, the nervous matter taken out, and laid upon two pieces of wood which were made to bridge over the wound of the skin. A continuous current was now applied to the posterior surface of the thigh, one electrode being placed to the foramen ischiadicum majus, and the other to the back of the knee-joint, the skin in both places being uninjured. A galvanometer was connected with the portion of the nerve that had been laid bare, and on closing the circuit the needle was seen to become deflected. *This deflection of the needle varied according to the direction of the current*; and it is therefore no longer allowed to be asserted that 'it is impossible to send a current in a certain direction through a nerve.'

In order to test the direction of a current passing through the spinal cord, the spine was laid open anteriorly; the bodies of the third and seventh dorsal vertebræ were drilled through, so that steel needles could be inserted into the cord. A continuous current was then directed to the cervical and lumbar spine, the electrodes being applied to the unbroken skin of the back. A deflection of the needle was obtained, and when the direction of the current was reversed, the needle was deflected in the opposite direction. An analogous experiment was performed on the brain. Two holes were drilled over the orbits, and in the centre of the parietal bones; steel needles were then inserted into the cerebral substance, for deriving a portion of the current. The electrodes were placed on the forehead and on the back of the head, and a deflection was obtained; on reversing the

direction of the current, the needle was deflected in the opposite direction.

The results of these and some other experiments of Burckhardt's, which we cannot detail here, show that *there is no difficulty whatever in sending a continuous current in a constant direction through the large nerve-trunks, the cord, brain, and cervical sympathetic nerve*; and as the living body is a better conductor than the dead, such a transmission of the current will be easier during life than after death.

Dr. Hitzig,[1] of Berlin, has very properly drawn attention to the circumstance that the whole controversy on Brenner's polar method is hardly worth the labour (and we may add, the excitement) which has been spent for the purpose of refuting or supporting it. It is true that the auditory nerve responds only to closing at the cathode and opening at the anode; but all the motor nerves answer to closing at the cathode as well as the anode. The polar method cannot, therefore, be maintained in that instance. In order, however, to show whether strictly polar effects are possible, Hitzig endeavoured to pass the current transversely through a nerve. Earlier experiments on this point had rendered it highly improbable that any response would take place under such circumstances. Hitzig used clay electrodes, provided with a transverse fissure, for receiving the nerves of two frogs' limbs, the thighs of the limbs being turned in opposite directions. Now, if strictly polar effects existed, the thigh in connection with the cathode should respond by contraction on *closing*, and the thigh in contact with the anode should contract on *opening* the circuit. The result, however, was absolutely *nil*. A contraction was only perceived if an enormous galvanic power was used; and even then it could be traced to the cur-

[1] Deutsche Klinik, 1872, p. 414.

rent having a certain direction in the nerve, caused by slight faults in the position of the electrodes and rheoscopic limbs. There are, therefore, no strictly polar effects to be shown experimentally in the frog's limb, and this is equally impossible in the living body. The result of this experiment entirely refutes Brenner's principle; and the only difficulty that has still to be met would be, to explain that wonderful galvanic response of the auditory nerve which has excited the enthusiasm of Brenner and his disciples. Hitzig accounts for this by the following considerations: The cathode is that portion of the closing arch where the current passes from the part to be examined and enters into another of a different nature. In the frog's limb this is the electrode, in the motor nerve of a man it is the soft parts surrounding the nerve; but in the auditory nerve the current is, as it were, directed into different parts before entering the nerve. Some portions of the current pass through the nerve in a direction towards the brain; and for these the point where the current leaves the nerve is no longer cathode, because the brain and the auditory nerve are not differently composed bodies. Physically speaking, the cathode influences the brain beyond the organ of hearing, and this is probably the reason for the apparent anomaly of the response of the auditory nerve. The latter would, therefore, represent simply the anelectrotonised portion of a nerve traversed in its longitudinal direction by the current.

The mode in which *faradisation* acts is not nearly so complicated, and therefore much better understood. For paralytic affections, the propositions which I laid down fourteen years ago in the first edition of this work are still in perfect consonance with our present enlarged knowledge of this subject.

They are as follows:—

a. *The faradic stimulus is capable of disturbing the molecular equilibrium of the motor nerves and muscles*

so as to produce the state in which they are physiologically active. This disturbance, if judiciously produced, does not cause any injury, but tends to re-establish or to ameliorate the lost or impaired function of the motor nerves and muscles.

b. *The faradic stimulus allows the necessary alternate contraction and expansion of the muscles, without which their nutrition is generally soon seriously impaired.*

c. *The faradic stimulus, by producing contractions of the muscles, and thus augmenting the chemical changes in —that is, the oxidation of—the contractile tissue, causes a more abundant supply of arterial blood to it, which is evidenced by an increase of heat and bulk in those parts which have been faradised, and which in its turn augments the nutrition of the muscle.*

In anæsthesia, hyperæsthesia, and spasm, faradisation acts in the same manner as static electricity, viz. by modifying the condition of the sentient nerves of the part submitted to its influence.

If it has been decided to adopt an electric treatment in a given case, and the special form of electricity to be used, as well as the mode of its administration, has been fixed upon, it further remains to determine how often it should be used, and when the treatment should be discontinued. In rare cases, one or two applications of electricity are sufficient to cure a patient; such being chiefly instances of hysterical and reflex paralysis, loss of voice, muscular rheumatism, and amenorrhœa. Generally speaking, however, it is necessary to use electricity for a month or six weeks, either daily or on alternate days, according to the severity of the affection for the cure of which it is employed. If the patient is well before the month is over, it is not necessary to continue the treatment; in some instances it may even be hurtful to do so. An example of this latter kind will be found in the

section on neuralgia. As all nervous affections are distinguished by their great tendency to relapses, further courses of galvanism are sometimes advisable, if symptoms which have in the first instance yielded to it should re-appear at any time after it has been discontinued. If the patient should not be well at the end of a month or six weeks, it is generally better to discontinue the treatment for one or two months, and then to recommence it. A second course of galvanism often rapidly cures symptoms which have obstinately resisted the first. Complaints in which the galvanic treatment may be continued without any interruption, until the patient is well, are progressive muscular atrophy and spinal and peripheral paralysis.

A good rule for practically settling such questions is the following: *Discontinue the treatment when the patient ceases to improve; or when he gets worse instead of better; or when symptoms of galvanic saturation of the system begin to make their appearance.*

In speaking of a *saturation of the system with galvanism* (a subject to which no previous writer has alluded), I do not mean a material accumulation of the galvanic fluid, which could be compared to the accumulation of certain poisons, such as arsenic, strychnia, or digitalis; of these we know that sometimes, after having been given in minute doses for a certain period without apparent effects, they suddenly cause violent symptoms, which must be traced to an undue quantity of them having accumulated in the system. But while arsenic may still be discovered in the system ten days after the last dose has been given, the galvanic current ceases to circulate as soon as the application is over. It is, therefore, only the *effects* of the application of galvanism which can give rise to symptoms of saturation. Faradic electricity never seems to lead to such symptoms at all, probably because it has no, or only slight, constitutional

action. The continuous current, on the other hand—which has a far more profound influence upon the central nervous system, and all the processes of nutrition throughout the body, than faradism—not unfrequently causes symptoms which, if present, should induce us to discontinue the treatment at least for a time. The most striking of these symptoms I have found to be a *persistent galvanic taste*, which does not disappear, as it generally does, immediately or soon after the application, but lasts the whole day and night afterwards, and sometimes even longer. Other symptoms of galvanic saturation are disturbed sleep, restlessness, singing in the ears, vertigo, and a general sense of lassitude. If these are perceived in the fourth, sixth, or eighth week of a galvanic treatment, they show that the system is becoming over-polarised, and that the galvanism has ceased to be useful. I have never continued the treatment under such circumstances, for the mere purpose of seeing what degree of over-stimulation might be reached, and what amount of harm a continued application might do in a given case. I am, therefore, unable to say what would ultimately be the result of such a proceeding. But I have no doubt that serious mischief would result by continuing the treatment, contrary to common sense, in such cases; just as we know that harm is done when the use of arsenic, digitalis, or strychnia, is pushed beyond reasonable limits. As a rule, nothing but discontinuance of the galvanic treatment is required for relieving symptoms of saturation; but if hyperæsthesia should be marked, twenty-grain doses of bromide of potassium, two or three times a day, for a few days or a week, would be appropriate.

I now proceed to consider the therapeutical effects of the different forms of electricity in those diseases for the relief or cure of which they have been, or should be, medically employed.

I.—DISORDERS OF THE MIND.

Most authors on electro-therapeutics are silent on this subject; yet it appears that, soon after the discovery of the voltaic pile, when the continuous current was used for every disease under the sun, in certain cases of mental disorders benefit resulted from a galvanic treatment. The earliest recorded case is one which occurred in the practice of Dr. Bischoff,[1] and which was that of a hysterical woman, aged 28, who suffered from paralysis of the right side, was continually crying, and in a high state of stupor, and who was cured of all these symptoms by a galvanic treatment. Augustin[2] speaks of a boy, aged 10, who after ague became subject to catalepsy and afterwards to paralysis, and who likewise suffered in his reason; but who, after three weeks of galvanic treatment, was cured of the paralysis, and became more brisk and energetic in his mind. Aldini,[3] Galvani's nephew, states that he has cured two persons suffering from melancholia by galvanism, and adduces the testimony of several physicians in corroboration of his statement.

Galvanism, however, soon afterwards fell into disuse, and it was not until Faraday had discovered the phenomena of induction, and after Duchenne had commenced to utilise that discovery for medical practice, that further therapeutical experiments with electricity in insanity were undertaken. Dr. Arndt[4] states that the rotatory apparatus was at one time very much employed in the German lunatic asylums, in the greatest variety of cases, and that it occasionally did a certain amount of good, but that as a rule the effect was *nil*. The

[1] Commentatio de usu galvanismi in arte medica. Jena, 1801.

[2] Versuch einer vollständigen systematischen Geschichte, &c. Berlin, 1803.

[3] Essai théorique et expérimental sur le galvanisme. Paris, 1804.

[4] Die Electricität in der Psychiatrie. Archiv für Psychiatrie und Nervenkrankheiten, vol. ii. p. 271.

patients disliked the application very much, and it was after a time only used for intimidating maniacs and abating violence. In some cases it evidently did harm. It is true that in cases of melancholia the mind at first became more open and clearer; but, as time went on, excitement took the place of melancholia, and increased to the most fearful violence. When the volta-faradic machines took the place of the old rotatory apparatus, they had a short period of popularity, but were soon put away as of no real use.

In France faradism had in the meantime likewise been used, and apparently with better results. M. Teilleux[1] began his researches on this subject in 1845, and found that, although the current was no specific remedy for insanity, yet it did good in well-selected cases. He looked upon it as a powerful stimulant, and used it in cases where anæsthesia, atony, and want of cerebral activity, were prominent symptoms. Abulia and depression were by its means relieved, while under certain circumstances it acted as a sedative, strengthened the power of the nervous system, and improved circulation. The following is one of Teilleux's cases:—

A woman, aged 35, had for several years suffered from a high degree of depression, lypemania, and hypochondriacal mania. Being of an intractable and irritable temper, habitually costive, and irregularly menstruated, she had to undergo great anxiety and privations, was infected with secondary syphilis, and finally became insane. She thought herself constantly persecuted, suspected everybody near her, refused food and work, and complained constantly of stomach-ache. She was treated for twenty days by faradisation of the skin over the brachial plexus, at the nape of the neck, the epigastrium, the loins, and the pelvic nerves; after which she had improved in appearance, her appetite and strength returned, circulation was more regular, and menstruation became re-established. She then had a course of iodide of iron and mineral waters, and was discharged cured three months afterwards.

[1] De l'application de l'électricité au traitement de l'aliénation mentale. Annales médico-psychologiques, 1859. Tome v. p. 353.

M. Auzouy,[1] like Teilleux, physician to the Asylum of Maréville, came to somewhat different conclusions. He looks upon certain peripheral phenomena not as complications, but as symptoms, of the cerebral disease, and considers that when they have once made their appearance they are of great influence upon the further progress of the case. An organ which, according to him, plays a prominent part in these conditions, is the skin, which serves to maintain animal heat at a proper standard, keeps the individual in contact with the world, and is of importance for perspiration and absorption. By its nerves it is intimately connected with the brain, and impressions made on the skin are transmitted to, and perceived in, the cranial centre. In lunatics the action of the skin is generally impaired, and often nearly lost. This condition should be combated by the physician, who may thus in an indirect manner act upon the brain itself. Magneto-faradism is, according to Auzouy, one of the best means at our disposal for this purpose. It causes a complete change, renews life, revives the functions of the skin which were in abeyance, accelerates circulation, and rouses the whole nervous system. It is therefore chiefly suitable for apathy and stupor, but it is likewise an excellent remedy for overcoming resistance and defiance, for inducing the patients to take food, and it may replace the strait-waistcoat and douche. M. Auzouy has related the following case:—

A brewer, aged 30, had, in consequence of irregular habits and the abuse of alcoholic liquors, got into a highly nervous condition, and ran one night, tortured by anxiety and remorse, to the house of his priest in order to confess himself. The priest did his best to convince him that there was no fear of eternal damnation. In this, however, he did not succeed; for the brewer persisted in thinking his sins so awful that they could only be expiated by a pilgrimage to Rome and Jerusalem. He therefore actually took

[1] Ibidem, p. 527.

the way there; but was soon taken up by the gensdarmes, and brought gagged to Maréville, where he was admitted on December 13, 1858. He appeared in a state of the deepest depression, did not answer any questions, and obstinately refused food. He suspected all with whom he came in contact, and cowered in a corner, with his head bent down, showing all symptoms of melancholia and stupor. He was aware of being touched, but did not show signs of pain when pricked, or when a seton was put. The handcuffs which the gensdarmes had put on him had so deeply cut into his thumbs as to cause gangrene; yet he felt no pain, and persistently tore off the bandage which had been put on to ease the wounds. There was decided analgesia. The patient was etherised, and afterwards faradised and douched. These latter two stimulants, at first used in a gentle degree, did more and more good as time went on, and four months after admission he was discharged cured.

These observations however did not succeed in restoring the confidence which had been so rudely shaken in the virtues of electricity in insanity. The continuous current became fashionable in the meantime; but such was the indifference with which electricity was regarded by alienists, that galvanisation was hardly practised in any asylum; and in a few exceptional cases where it was used it failed to do any good.

Cæsar Lombroso[1] has studied the alterations of electric excitability which occur in insane patients, and found that this is considerably diminished in persons suffering from pellagra and dementia. In apathetic melancholia it was likewise diminished, while in the erethic form of that disease it was occasionally increased. The extensor muscles responded, as a rule, more feebly to the faradic current than in healthy people, and the heart's action was increased after faradisation.

Remak has incidentally stated that he has seen good results from the use of the constant current in morbid conditions of the brain accompanied by disordered mental functions; and Benedict[2] has recorded three cases in which mental symptoms

[1] Klinische Beiträge zur Psychiatrie. Deutsch von M. O. Fränkel. Leipzig, 1869.

[2] Loc. cit. p. 203.

were improved by galvanisation. One of these was the case of a musician, aged 42, who suffered from general prostration, vertigo, impaired memory, deficient power of application, and distressing sensations in the head. The continuous current was applied along the spine; after six applications the patient could walk without support, and by further treatment all the head symptoms were considerably improved, so that he could return to the active exercise of his profession. The second case was that of a cabman, aged 57, who suffered from extreme weakness of memory, and was apt to burst into tears on the slightest occasion. After a few weeks' galvanisation he was much better in every respect, and laughed when his previous depression of spirits was alluded to. He was enabled to return to his business. The third case was that of a half-idiotic boy, who was likewise improved by galvanisation of the brain, although not to any very great extent. Benedict is of opinion that these mental disturbances are caused by affections of the vaso-motor nerves, and may be cured by his favourite proceeding of galvanisation of the sympathetic, which promotes the absorption of effusions, and thereby removes pressure on the nervous matter. He considers most diseases of the mind as arising from swelling of the meninges and the cortical matter of the brain, which ultimately leads to sclerosis. Upon this condition the continuous current has a powerful influence, more especially upon that form which is called diffuse sclerosis of the nervous centres. Tumours of the brain also give rise to mental disturbance in consequence of vascular excitement, in the same way as giddiness, headache, and other symptoms are produced by it. More recently the same author [1] has resorted to faradisation of the skin of different parts of the body, and of certain sets of muscles, in cases where there is absence of mental excitement; but where excitement is present, he recommends the application of the continuous current to the head and the sympathetic. Benedict states that he has cured by this means a case of extreme depression, combined with delusions, hallucinations, and 'monomanie des grandeurs,' in eight weeks. Another case was that of a girl, aged 16, who, after a fever, became exceedingly restless, melancholic, and nearly paralysed in the right side. The movements of the face and the tongue were very sluggish, and soon seemed to exhaust the patient. On

[1] Allg. Wiener medicin. Zeitung, xxxi. 1870.

faradising the muscles of the arms, both pupils became dilated. After six weeks of faradic treatment she was much improved.

Dr. Arndt,[1] of Greifswald, has gone more deeply into this subject than any previous observer, and is inclined to look upon electricity as an invaluable remedy in certain forms of insanity. He believes it to be equally important as quinine, iron, and baths, and far more important than narcotics in the treatment of mental disease. The reason why up to the present time not more has been done with electricity is, according to Arndt, that the applications have been unsystematic, and that alienists have not been sufficiently critical in their selection of cases. He has found that faradisation does no good in melancholia, and that where this form of insanity is combined with distressing ideas of persecution, &c., the faradic treatment makes the patient actually worse. In the so-called secondary forms of insanity faradism likewise does harm; and in apathetic idiots it seemed to induce fainting fits. Faradisation does a great deal of good, however, in *simple depression*; such patients become more lively, seem to take renewed interest in what is going on, and resume their working habits.

The following is one of Arndt's cases:—

A married lady, childless, had repeatedly been in asylums. She did not show any particularly striking symptoms when she came under treatment, but was absolutely indifferent to everything that was going on. No smile, no tear, no expression of anger, appeared to show that anything affected her in any way whatever; and she seemed only to vegetate. She would do nothing for herself; in the morning she had to be taken out of bed, dressed, and fed. After this condition had lasted for several months, without being in the least altered by the remedies employed, faradism was used, principally to the extremities, and only rarely to the neck. After the first application, during which the patient shed tears, there was a decided improvement; she

[1] Loc. cit. p. 259.

appeared more lively, and took notice of things which were going on around her. On being encouraged by the nurse, she began to talk, spoke about her previous mode of life, and recited poems. Faradism was used two or three times a week; and in two or three weeks the patient was so much improved that she could be looked upon as convalescent. This favourable condition continued; but she could not be considered cured, as there was a certain amount of mental weakness, which could not be overcome; she appeared occasionally silly and foolish. Some other cases of Arndt's were even more successful; but their record is so long that space forbids me to adduce them.

Arndt considers that *faradism acts as a powerful stimulant upon the diseased nervous centres*, and that it should therefore not be employed where the symptoms point to increased excitability, *i.e.* in all so-called primary cases, where undue cerebral excitability is evidenced by ruling affections, whether positive or negative in character. It also does not answer in secondary cases if these be marked by a high degree of irritable weakness, and a tendency to reflex actions. On the contrary, faradism is an excellent remedy for cases of simple atony of the brain, depression, or paralysis of function. It is quite true that, even if the physician be guided by these general rules, he may yet sometimes be unsuccessful in his treatment; for some conditions of excitability are not owing to irritation, but to paralysis; and some forms of stupor may be caused by spasm, and not by depression. Since the discovery of the inhibitory system of nerves, we must be prepared to find that mental disease may proceed from that source; and irritation of the inhibitory nerves may cause inhibition of energy, while paralysis of these nerves may produce increased function. Experience shows that most forms of mental paralysis are preceded by a stage of irritation; and in recent cases of insanity the mere depression of certain functions must therefore not be looked upon as a symptom of debility, but of inhibition, in consequence of irritation of

certain inhibitory nerves or their centres. This principle is especially applicable for cases where symptoms of irritation are present in other organs; for instance, where respiration is sighing or jerky, where there is much singultus or gaping, irregularity of the heart's action, dilatation of the pupils or differences in their size, spasms of voluntary muscles, &c. Where, however, no such symptoms are present, a depressed condition of the brain may be diagnosed with a high degree of probability. The central stimulation produced by faradisation is not a direct one, but owing to transmission of the stimulus from the sentient nerves of the skin to the brain. In faradisation of the skin we therefore appear to possess an excellent remedy for acting indirectly upon the diseased brain and spinal cord.

Arndt also resorts to faradisation of the phrenic nerves at the neck in these cases. The brisk respiratory movements caused by this proceeding are probably useful in decarbonising the blood, improving circulation, and removing or preventing that passive hyperæmia which is so frequently found in the blood-vessels of the pia mater. Arndt considers faradism very analogous in its action to cold baths, the douche, and other stimulating applications of cold water; in all cases where these answer, faradism will do good, and *vice versâ*. Faradism has, however, the advantage over the latter, by being more manageable and more easily controllable in its action, while it is devoid of unpleasant consequences, as patients do not catch cold after it. It is never actually strengthening, nor does it act as a specific; and it is therefore necessary to employ other means at the same time for improving the nutrition, &c. Where decidedly alterative effects are required, it is best to resort at once to the constant current.

In using *galvanisation*, Arndt thinks it important not to employ the small portable batteries, which have a more stimulating effect than the large ones, and to avoid carefully

any variations of the current, or voltaic shocks, which occur if the battery is not kept in good condition. Otherwise we must be guided by Pflüger's principles, viz. to produce anelectrotonus where a sedative effect is desired, where irritability has to be diminished; while catelectrotonus should be caused where there is depression of energy, and paralysis of function. Whether the current is direct or inverse is not of so much importance as the two forms of electrotonus. With a direct or descending current anelectrotonus is produced in the centre, and catelectrotonus in the periphery; while with the inverse or ascending current, catelectrotonus appears in the centre, and anelectrotonus in the periphery. This is the reason why the inverse current acts more powerfully as a refresher and reviver of the nervous system than the direct. The galvanic power which is to be used must be judged according to Pflüger's law of contraction. A feeble current is one where only a contraction takes place on closing, whether the current be direct or inverse; a current of medium intensity is one which causes a contraction on closing as well as on opening; and a powerful current is one where there is a closing contraction with the direct and an opening contraction with the inverse current. For galvanising the cord in these cases, Arndt recommends to put only that electrode to the spine the special action of which it is intended to produce, and the other one either to the sternum, or to the abdomen, or to the limbs.

Although every form of insanity is a symptom of diseased cerebral action, yet it would be a mistake to believe that coarse structural alterations of the brain-matter are always present in these cases. Arndt thinks, on the contrary, that they are absent in by far the largest majority of cases; and where they are discovered, they are more the consequences than the causes of disordered function. In most cases of insanity there is nothing but a disturbance of the finer mole-

cular changes of nervous matter, which is manifested by increased mobility of molecules, and which is known as augmented impressionability, vulnerability, irritable debility, nervousness, neuropathic temper, or diathesis.

Experience has shown that in the various forms of insanity it is not the mind alone which is diseased, but that other nervous affections often precede for years the outbreak of the mental disorder, and which have generally to be traced to a pathological condition of the spinal cord or the medulla oblongata.

Proceeding from this fact, Arndt recommends to apply the constant current not so much to the head as to the peripheral nerves and the spinal cord, which are generally in an irritable condition, and require to be placed into the condition of anelectrotonus. The peripheral nerves will have to be acted upon first, where the mental disease has commenced with, or followed, an attack of neuralgia, and in such cases the painful nerve should be galvanised; and, secondly, where the mental symptoms become worse, as soon as peripheral affections, such as laryngeal spasm, dyspnœa, palpitations of the heart, &c., make their appearance. In the latter case the pneumogastric nerves should be galvanised. Where, on the contrary, the symptoms are not shown to be dependent upon any peripheral irritation, or kept up by disturbance of peripheral functions, but where they point to an affection of the nervous centre, the current should be chiefly directed to the cord. Cerebral galvanisation appears only suitable where a temporary soothing or stimulating effect is desired. Where structural disease has already commenced, the galvanic current appears to do no good, and should not be used. In cases where disease of the ovaries, womb, or bladder has led to disease of the cord, or where there is a general disturbance of nutrition throughout the system, as in anæmia, chlorosis, syphilis, rheumatism, the battery current is generally of

great service in preventing any irremediable changes of structure and removing the causes of mental disturbance. *Recent cases and functional diseases, therefore, are benefited by, while old cases and structural diseases resist, the influence of galvanisation.*

Arndt has given a lengthy description of five cases he has treated by the aid of the constant current, but which space prevents us from transferring to our pages. In three of them there was evidently an irritable condition of the central nervous system, with debility and incipient paralysis. The symptoms of irritation were hyperæsthesia, increased reflex excitability, and conceit. The paralytic symptoms affected chiefly the muscles of the extremities, face, and articulation. Unilateral dilatation of the pupil and sluggishness of the iris to the stimulus of light was considered a symptom of spinal irritation, and disappeared with the other signs of irritation of the cord. There were likewise numerous symptoms pointing to an affection of the vasomotor system of nerves, which had preceded the outbreak of mental disturbance for a considerable time—such as sluggish digestion ; constipation from want of expulsive power of the bowel; varicosities near the anus; increased perspiration and secretion of urine ; heat in the head, fulness, pain, giddiness, tinnitus aurium; or anæmia, pallor of the skin; the eyes were either bright, the pupils constricted, and the pulse soft and slow, or there were dull eyes, dilated pupils, a small and rapid pulse. In another case the disease was of a more spasmodic character; the vessels were constricted, respiration and the heart's action irregular. All these cases were nearly cured by the induction of anelectrotonus. That this should have been useful for incipient paralysis is an apparent contradiction ; but it should be considered that the essence of the disease was undue irritability, leading in its turn to exhaustion and paresis. As soon, therefore, as the causative condition (*i.e.*

excessive irritability) was removed by anelectrotonus, the symptoms disappeared. In one case where paresis owing to irritation was a prominent symptom, catelectrotonus was tried, but gave bad results; and when anelectrotonus was substituted for it, the patient improved. Arndt considers the constant current is likely to become in course of time the most important remedy at the disposal of the alienist physician.

Dr. Williams,[1] of Hayward's Heath, has recorded the good effects of galvanisation in two cases of melancholia attonita, with refusal of food, which he treated in the Sussex Lunatic Asylum. Although he has said nothing about the mode of application, the cases are nevertheless sufficiently interesting to be placed on record here.

J. L. B., male, aged 51, single. Had an attack of brain fever when about eighteen years of age. Enlisted August 3, 1855, into the 7th Royal Fusileers, at the age of twenty-nine. Has served in Malta and East India. Had an attack of sunstroke in India about two years ago, when he was in the hospital there, and discharged as unfit for service. Conduct during service very good; is considered to have been steady and temperate. Admitted October 19, 1872, in a very weak, low, and emaciated state; pulse 160; tongue coated, appetite bad; bowels confined. There is great irritability of the pectoral muscles, and the respiratory murmur is weak and indistinct, especially posteriorly, where there is probably some consolidation of the lower lobes. Heart's action weak. He is not wholly conscious, and does not attend to questions without great rousing. Such was his state on admission, and up to October 28 he gradually became worse. The stupor was much increased, the refusal of food became more obstinate, and the physical symptoms knew no abatement. On that day Dr. Williams requested his colleague, Dr. Newth, to pass a continuous current through his head from a forty-cell Stöhrer's battery. The immediate effect was to increase the heart's action and to cause considerable flushing of the head and face. The treatment was continued daily. He almost imme-

[1] The Lancet, January 25, 1873.

diately improved, became more and more conscious, took nourishment well, and on November 2 was so much better that he was able to sit up for several hours. From thence he improved rapidly, and within a few days all the acute symptoms, both mental and physical, had subsided.

J. W., male, aged 45, was found wandering about Brighton. History unknown. Admitted December 5, 1872. He was a fairly well-formed man; tongue coated; bowels confined; respiratory murmur decidedly weak in both lungs, and there is a suspicion of congestion in the right; heart's sounds weak and nearly inaudible at base; pulse 112. He can rarely be got to attend to any question, and when he does answer his language is rambling and incoherent; memory very bad; spirits depressed, and there is considerable excitement and restlessness of manner; will not keep quiet for an instant; expression wild; nights sleepless. Up to December 13 he gradually became worse; refused his food, and the mental depression became so intense as almost to amount to stupor. Electricity was tried by Dr. Newth for about seven minutes. He was much excited when under it; restless during the night afterwards, but took a fair amount of food for the first time for several days; pulse 140, weak; catheter passed.

December 13.—Had the electric current for about ten minutes. Pulse 136, fuller; quieter.

14.—Electric treatment repeated; pulse 130, much stronger.

16.—Continues to improve.

17.—Violently resisted the application of the electric current. Pulse 112, full and regular; he is quieter and more rational; takes his food well.

The treatment was continued for several days longer—viz. to the 21st, when he was so much better, indeed convalescent, that it was omitted.

II.—CEREBRAL EXHAUSTION.

The chief symptoms of cerebral exhaustion, on which Dr. Radcliffe[1] has lately delivered an able lecture, I have found to be the following:—Nervousness, irritability of temper, want of mental energy, impaired memory, a sensation of

[1] British Medical Journal, April 12, 1873.

weight and pressure at the top or back of the head, drowsiness, giddiness, hesitating or embarrassed speech, flushings of the face, sensations of tingling and numbness in the extremities, rapid exhaustion of muscular power from exertion, palpitations of the heart and dyspnœa, various forms of dyspepsia, irritability of the bladder, loss of the desire and capability of sexual intercourse, a jaded appearance, and frequently an immoderate craving for alcoholic stimulants. All these symptoms are, of course, not present in every case of cerebral exhaustion; and many of them may be present in disease of the cerebral blood-vessels and brain-matter; nevertheless the group of symptoms just mentioned is very marked in a considerable number of cases which come habitually under our notice; and that they are owing more to functional derangement, and a bad performance of the finer processes of nutrition which escape our present means of anatomical investigation, than to structural disease, is shown by the circumstance that most of these cases recover. The condition of anæmia seems to be more prevalent than that of hyperæmia in these cases; and the almost invariable cause is, not hard work, but worry, anxiety, and affliction.

The medicinal treatment of cerebral exhaustion often yields but unsatisfactory results. The patients' sufferings are at first generally looked upon as arising from 'congestion of the liver,' and the aid of blue pill is called in. After a time, however, it is seen that a more tonic plan of treatment is required, and the sulphate or the tincture of iron is given, frequently in large doses, which are apt to upset the stomach and the liver. Bromide of potassium is then substituted; but the patient, as a rule, derives only little benefit from any of these medicines. Change of air and scene, rest for the mind, with phosphorus and nitrate of silver for internal use, are more successful; yet many cases occur in which even such a plan of treatment does not answer, and the constant

current should then be employed. I look upon galvanisation in these cases as by far the best remedy at our disposal; but its use should always be combined with such general and dietetic directions as may appear advisable.

As a rule, I have found it best to produce catelectrotonus rather than anelectrotonus of the suffering nervous centres. Even where symptoms of irritability and restlessness are prominent, these are generally owing more to impaired nutrition of brain-matter than to vascular excitement. The result of the treatment itself, however, must in the end be decisive, and overrule any theoretical views we may have formed of the nature of the case. Where catelectrotonus does not answer, or makes the patient worse, anelectrotonus should be tried; and if the patient does not improve rapidly under either plan of treatment, the use of the current had better be given up.

Wherever sleeplessness is a prominent symptom, the production of anelectrotonus should be the rule. Catelectrotonus, on the other hand, is an excellent remedy where there is drowsiness in the daytime.

CASE 7.—A merchant, aged 48, widower, consulted me in March 1867 for nervousness and irritability of temper. He had for years past experienced considerable anxiety in business, to which he attributed his illness. He complained of a sensation of weight and pressure at the top of the head and in the temples, and of dizziness, chiefly on stooping and looking upwards. His memory and power of application were very much impaired. The speech was somewhat affected, so that he would stop in the middle of a sentence, hesitate for a few seconds, and then abruptly finish it. Whenever anything unexpected or disagreeable occurred, he became flushed in the face, had sensations of tingling resembling slight electric shocks running down his hands, and would for the time completely lose the faculty of speech. The right pupil was larger than the left, and the sight was often dim. The temperature of the right cheek was 88° and that of the left 87° F. The right ear was also hotter than the left. The pulse was sometimes intermittent and irregular, and the patient complained of

palpitations of the heart and shortness of breath in walking, more especially on going upstairs, but there was no disease of the heart or lungs in this case. The tongue was dry and thickly coated, the appetite indifferent, and a sense of fulness and heaviness was experienced after meals. The action of the bowels was irregular. The urine contained an enormous excess of phosphates, but not of urea, and the expulsive power of the bladder was diminished. The patient had become very stout during the last few years, and his muscles were flabby. He rarely took active exercise, as it seemed to make him worse. He had already taken iron and quinine, strychnia, belladonna, and bromide of potassium, but without any improvement. For the last eighteen months he had felt too feeble to attend to his business.

In this case catelectrotonus of the spine, the cerebral hemispheres, and the sympathetic, was resorted to with satisfactory results. Almost all the morbid symptoms gradually yielded to it, and ten weeks after the commencement of the treatment the patient was enabled to return to his business. He found that he could work well for about a couple of hours, but that when he went beyond that, the symptoms of pressure on the head and tingling in the arms were apt to return.

The patient had another, but much shorter, course of galvanisation in November 1867, and again in June 1868, when several of the old symptoms had reappeared. On both these occasions they yielded rapidly to the influence of catelectrotonus; and when I saw him last (May 1869) he was, although not strong, yet in good health, and had been enabled, by restricting his hours of work, to attend to his business without any interruption.

Dipsomania and Excessive Spirit Drinking.—I am inclined to believe that a systematic use of the constant current would prove of service in dipsomania. Up to the present time I have only treated one case of this affection, with apparently good effects; but I have seen many instances where mental depression and nervousness were so great that the patients had long been in the habit of taking excessive quantities of stimulants, in order to deaden the acuteness of their wretched sensations; and where the morbid desire for alcohol was rapidly checked as soon as they were fairly brought

under the influence of catelectrotonus of the spine, the cerebrum, and the cervical sympathetic. One of these cases is the following:—

CASE 8.—In June 1868 a lawyer, aged 37, married, came under my care, who had, in consequence of overwork and anxiety, got into a state of complete nervous derangement. He was utterly incapable of any mental or bodily exertion before he had taken three or four ounces of brandy (in the morning), and was in the habit of consuming rather more than a pint of spirit every day. He hated the very sight and smell of brandy; but if he did not take it, such horrible thoughts came into his head as to render life perfectly intolerable. His judgment and intellect were not impaired, but he had not the slightest control over the dreadful ideas which constantly flitted across his brain if not under the influence of alcohol, and which were chiefly of a homicidal and suicidal character. Tonics of every kind made him worse, and several alteratives of considerable efficacy (such as bromide of potassium and bichloride of mercury) had apparently increased his debility to such an extent as to render a prolonged course of them impracticable. Under these circumstances the application of the constant current to the nervous centres seemed expedient. Within a week from the commencement of the treatment the patient was able to discontinue the brandy in the morning. After three months he had come down to half a pint of sherry for dinner, and took no spirits whatever. His mental and bodily health improved *pari passu*, and when I saw him again in March 1869 he appeared perfectly well, and had lost every symptom of his previous illness. In this case the current was applied forty-five times. No medicine was given.

Opium-eating.—In this country opium-eating is not unfrequently contracted during severe attacks of neuralgia, or after family afflictions. The habit is rarely broken through, if it has once gained the mastery over the patient, as the feelings of depression and despair which invade the mind after the comforting effects of the drug have passed off are so acute as to be almost unbearable, and only yield to a fresh supply of it. Under such circumstances galvanisation appears appropriate.

CASE 9.—A lady, aged 48, widow, had commenced to take laudanum after the loss of her husband, six years ago. When she came under my care in October 1867, she complained of indigestion and weakness in the back, which latter prevented her from standing or walking. She had a great aversion to taking medicine, and consulted me chiefly with regard to the application of galvanism in her case. She never mentioned that she was in the habit of taking opium, but laid stress on the symptoms of constipation and want of sleep. The latter symptom only induced me to treat her with anelectrotonus of the brain and sympathetic, while for the weakness in the back I should have been satisfied with an application to the spine. No medicine was given, except Friedrichshall-water for constipation, with good results. Under the influence of anelectrotonus sleep improved and the back became much stronger, so that the patient was soon enabled to take a good deal of active exercise. Although after a time she appeared in fair health, she still appeared anxious to continue the galvanic treatment; and one day confessed to me that she had been in the habit of taking large quantities of laudanum for years past, to which she attributed her illness; but ever since the galvanic current was first applied, she had felt less desire for opium, and that she had gradually discontinued the use of it. She was afraid that if the galvanic treatment were given up, the desire for opium would return, and as she found herself much better without it, was anxious not to be obliged to do so again. A short time afterwards the treatment was, however, discontinued, the patient being desired to return if any symptoms of opium-hunger should present themselves, but up to the present time she appears to have had no return of that morbid desire.

Excessive Smoking.—Tobacco-smoking is often resorted to for the same reason as spirit-drinking and opium-eating, viz. to allay nervous irritability and depression; and is by many people carried to such an extent as to seriously injure, not only the function of digestion, but also the nutrition of the nervous system. Such patients say that they *must* smoke, as others *must* drink. In several cases of this kind which have been under my care, the use of the constant current, coupled with strong remonstrances on my part, has enabled the patients to break themselves of the habit.

In *Hypochondriasis*, galvanisation of the brain, spine, and cervical sympathetic is often attended with satisfactory results. To produce catelectrotonus is, as a rule, the best plan of treatment, which answers particularly well in cases where the hypochondriasis is connected with imaginary or real disease of the sexual organs (sexual hypochondriasis, spermatorrhœa, impotency), and galvanisation of those parts must then be combined with the application of the current to the nervous centres.

III.—PARALYSIS.

In the various forms of paralysis, both faradisation and galvanisation find a legitimate and useful sphere of action. The mode of application, and the amount of benefit to be expected from it, depend entirely upon the pathology of the different cases, and this we therefore now proceed to consider.

1. *Cerebral paralysis.*—The most frequent form of cerebral paralysis is hemiplegia, which is generally owing to cerebral hæmorrhage, softening, or embolism of an important cerebral artery. Such pathological processes impede the conduction of the orders of volition, which in the normal condition are carried through the fibres of the corpora pyramidalia to the motor nerves of the opposite side of the body, to the muscles, so that these become incapable of executing voluntary movements.

If the patient survive the paralytic stroke, a process of reparation commences in the cerebral substance, which is more or less thorough according to the degree of the paralysing lesion. Where the corpus striatum is entirely destroyed by effusion of blood or softening, paralysis of the opposite side of the body will not only be complete, but also permanent. In cases of paralysis or paresis, however, where only

an effusion of a small quantity of blood into that central ganglion has taken place, this may in course of time be absorbed, and the patient's health may be gradually restored. At first the fluid parts of the effused blood are absorbed, and a cyst is formed round the clot, which in course of time likewise disappears. The cyst then shrinks up, and at last only a cicatrix is found. In some cases this process of reparation is accompanied by a gradual amelioration of the paralytic symptoms, and spontaneous recovery may take place. In other instances the gradual shrinking of the cyst acts as an irritant on the brain; the paralysed muscles then assume a rigid condition, and the motor nerves undergo various pathological alterations. Finally, the cicatrix may have been formed, and there may be no rigidity of the muscles, but the paralysis still continues in a more or less degree, owing to the function of the injured hemisphere remaining in abeyance, from hyperæmia, serous effusion, or the effects of shock.

Embolism of cerebral arteries occurs in patients affected with disease of the aortic or mitral valves owing to former endocarditis. Particles of fibrin are suddenly separated from the warty growths on these valves, are carried along with the stream of blood, and plug up a cerebral artery. The prognosis is generally unfavourable, not only because softening takes place in the neighbourhood of the embolus, but also because there is great probability of further attacks occurring in course of time, even if the first symptoms should have been removed by the establishment of collateral circulation. These cases, however, are much rarer than those owing to cerebral hæmorrhage, which latter furnish by far the largest proportion of all cases of hemiplegia.

When an extensive laceration of cerebral substance has taken place, either by hæmorrhage or softening, or when the shrinking of the cyst has caused rigidity of the paralysed

muscles, the prognosis is unfavourable. But where the clot or softening is of limited extent, and consequently the cicatrix is not very large, the prospects are much better, even if no spontaneous recovery takes place. It is probable that the process of reparation in the brain may be promoted or accelerated by the use of the constant current; and that by this means the parts in the neighbourhood of the paralysing lesion, which have become unable to fulfil their function through hyperæmia, serous effusion, or shock, may thus be enabled to regain their function.

The following case occurred in Benedict's [1] practice :—

A merchant, aged 69, had had an attack of right hemiplegia in August 1862, with loss of consciousness and language. In May 1863 the leg had recovered, but all the muscles of the forearm and hand, with the only exception of the muscles of the ball of the thumb, were paralysed, and the flexors and pronators were contracted. Electro-muscular contractility was considerably diminished. The continuous current was applied to the left cerebral hemisphere, and *immediately afterwards* the patient could flex the wrist and the phalanges. After five more applications he could extend the metacarpo-phalangeal joints fairly well, and the phalangeal joints pretty well.

I have never seen such immediate results in hemiplegia, merely from galvanisation of the injured cerebral hemisphere; but experience has shown me that patients of this kind progress more rapidly towards recovery when cerebral is combined with peripheral galvanisation; and I therefore generally employ both methods together.

Only the *continuous* current should in such cases be applied to the injured cerebral hemisphere. Faradisation by a feeble current has no effect on the nervous centres, and it might do harm if a high degree of power were used. Several cases have occurred in M. Duchenne's [2] practice, where, by the injudicious application of faradic electricity to patients

[1] Loc. cit., p. 227. [2] Loc. cit., p. 274.

who had suffered from cerebral hæmorrhage, another attack of paralysis was caused.

How soon after the attack should the treatment be commenced?

Remak has recommended to galvanise early the sympathetic and the cerebral vessels of the side opposite to the paralysis, in order to promote the absorption of the clot; and Onimus and Legros [1] have recently endorsed this opinion. They say that galvanisation of the brain and sympathetic may be commenced seven or eight days after the attack. The anode should be placed on the forehead of the side of the lesion, and the cathode to the nape of the neck. A current of six or eight cells is thus caused to pass through the injured hemisphere for two or three minutes. Afterwards the superior cervical ganglion is galvanised with a somewhat more powerful current, viz. from ten to fifteen cells, for about five minutes. It is indispensable to commence the operation with a very feeble current—only one or two cells—and to increase the power slowly and gradually; and the same precaution should be observed when the current ceases to pass. Voltaic shocks must be carefully avoided.

According to the authors just named, such an operation promotes the absorption of the clot, by moderately influencing circulation; and such an influence may likewise be useful in cases where the hemiplegia is owing to plugging of the cerebral blood-vessels, and consequent failure of cerebral circulation. The process of absorption is generally finished about thirty or forty days after the attack, and the cyst has then been formed. The current is generally used only then, or even two or three months after the attack. At that period it would be very difficult to act on the lesion itself; the utmost one could expect would be, to prevent secondary

[1] Traité d'Électricité médicale. Paris, 1872, p. 503.

atrophy of the nervous elements which are in anatomical and physiological connection with the seat of the cerebral lesion. But even that appears doubtful, and the results of the treatment depend upon the degree of severity of the disease.

I think it absolutely necessary to postpone a galvanic treatment until the danger of cerebral fever, which so often follows an attack of hæmorrhage, should have passed off; and as this, if it occur at all, comes on in the second or third week, the application of the continuous current may be considered safe when from fourteen to eighteen days have elapsed since the occurrence of the attack. If we were to wait much longer, the prospects of ultimate recovery would certainly be diminished. Professor Türck,[1] of Vienna, has shown that, if the paralysis continues for six months or longer after cerebral hæmorrhage or encephalitis, atrophy of the nervous fibres of the opposite antero-lateral columns of the spinal cord is apt to come on. Granular cells and elementary granules are formed, which appear at first singly, but later on in large masses, above the origin of the nervous plexuses of the upper and lower extremities. When this process has reached a certain stage, any further therapeutical efforts must inevitably fail; and *pathological anatomy thus plainly warns us not to defer the galvanic treatment of cerebral paralysis longer than a short time after the occurrence of the attack.*

In cases where the current is applied early—that is, about three weeks after the occurrence of the attack—it is sufficient to resort to galvanisation of the injured hemisphere and cervical sympathetic of the same side, producing anelectrotonus. As a rule, after a few applications there is greater ease in the head as well as in the limbs; if there has been

[1] Sitzungsberichte der mathem. naturwiss. Classe der k.k. Akademie der Wissenschaften zu Wien.

pain, this is relieved, and the motion of the hands and feet becomes re-established. The arm is generally more sluggish to recover than the leg, and the recovery always proceeds in a direction from the centre to the periphery.

In cases where several months have elapsed since the occurrence of the attack, galvanisation of the brain and cervical sympathetic alone is not sufficient; and peripheral galvanisation or faradisation should then be combined with it. In such cases we assume that the paralysis is no longer exclusively due to the injury of the affected hemisphere, but also to a great extent to the loss of vital energy of the nerves and muscles of the affected limb, the molecules of which have lost that mobility which previously enabled them to respond to the orders of volition. Whether in such cases galvanisation or faradisation should be resorted to, will depend upon the individual aspect of the case under treatment; and it may be laid down as a general rule that, where the electro-muscular excitability is normal, galvanisation, and where it is diminished, faradisation, should be employed. It is often useful to combine both methods, or to employ one after the other has been used for some time and failed.

We have already seen that in some cases of hemiplegia the paralysed muscles are relaxed, the limbs loose and flaccid, and if the fore-arm be flexed upon the arm, or the leg upon the thigh, no resistance to that movement is experienced. The paralysed muscles present a striking contrast to the firmness and plumpness of those of the sound side, and they are more or less wasted according to the length of time which has elapsed since the paralytic seizure. In such cases there is generally only little response to the galvanic and faradic stimulus, and the heat and nutrition of the limbs are much below par. Some of these cases recover spontaneously, while others only slightly improve as time goes on. Where recovery is imperfect, faradisation is a valuable means of

restoring power to the motor nerves and muscles which remain paralysed, and require a stimulus in order to regain their function. Moistened electrodes should be directed to the suffering nerves and muscles. The old-fashioned way of using the induced current in these cases, viz. to let the patient hold one conductor in the right and the other one in the left hand, or to place his feet in two separate vessels filled with salt water and connected with the poles of a battery, is to be strongly deprecated, as by such a proceeding painful and irregular commotions are caused in the paralysed as well as in the healthy muscles, which are indiscriminately affected. This method of operation can therefore not be beneficial to the patient. On the contrary, it has often done harm by causing cerebral irritation and increasing the contractions. The following is a case in which only a few muscles remained paralysed after the stroke, and in which faradisation was beneficial:—

CASE 10.—Jane S., aged 35, was in July 1857 admitted into Carlisle ward, St. Mary's Hospital, under the care of Dr. Alderson. From the somewhat confused statement of the patient, whose intellect and memory are below the average, I concluded that she broke a blood-vessel in the right corpus striatum fifteen months ago, in consequence of which she lost consciousness and the use of the left arm and leg. The leg appears to have soon recovered; for, when I first saw her on July 20, she could walk pretty well, but several muscles of the left arm were paralysed, viz. the deltoid, the extensor of the forefinger, and all the muscles of the thumb. She could raise the humerus, this movement being produced by the concurrent action of the trapezius, serratus magnus, and deltoid, but she was not able to lift the arm to a right angle with her body, and when she held the hand on the lower part of the spine, she could not move it upwards. The forefinger was slightly contracted, and could not be extended; the thumb was held against the forefinger, and was totally powerless. All the affected muscles were flabby and wasted. The patient was not able to use her needle or do any other work. When I directed the faradic current to the paralysed muscles, they showed much

less excitability to it than the corresponding muscles of the other side. The deltoid was much improved after five applications, but the muscles of the forefinger and thumb recovered only after a month's treatment, in which faradisation was used about twenty times. The patient then left the hospital, being again able to use her needle and to accept a situation as cook.

Where the hæmorrhage has been so extensive as to destroy the corpus striatum nearly or altogether, no benefit accrues from faradisation, or in fact from any other plan of treatment. The following is an instance of this :—

CASE 11.—In May 1858 I was consulted in the case of a merchant, aged 60, married, who had been in tolerably good health until December 1857, when he was knocked down by a cab. With the exception of some bruises on the back and the leg, no apparent injury was caused by this accident, but the day after he was seized by an attack of hemiplegia, which affected the whole left side of the body. He did not lose his speech nor his consciousness. The face recovered rapidly, but the arm and leg remained completely useless. He could pull up his shoulder to some extent, but was unable to lift the hand to the forehead or put it on his back, or on the opposite shoulder; nor could he bend the elbow or move the wrist in any direction. He had to be lifted into, and out of, his bed, and everything had to be done for him as for an infant. There were hardly any contractions in the muscles, which were flabby, and responded only a little to the faradic current. His general health was tolerably good. Faradisation was used for six weeks, but with no perceptible effect, the condition of the patient remaining much the same as before. The muscles of the limbs which had been faradised were better nourished and answered more readily to the current than before; but there was no return of voluntary power.

Where the nerves and muscles of the affected side are equally excitable to electricity as those of the healthy side, the continuous current is more appropriate than faradism; and provided the original injury has not been too severe, it may prove decidedly beneficial.

CASE 12.—A clergyman, aged 46, married, had an attack of cerebral hæmorrhage in September 1868. He had for many years

worked hard in his parish and undergone much anxiety. He had never exceeded in drinking or smoking, and there were no nervous affections in his family. When I first saw him in December 1869 his intellect was good, his memory rather worse than before, and his power of application much diminished. His temper was irritable, but he did not suffer much from despondency. The sight and the motor nerves of the eye were in good condition, but he complained of tinnitus aurium ever since the attack. The tongue was tremulous when protruded, and there was lateral deviation of its apex. He had suffered a great deal from headache before the attack, but never since. One of the principal symptoms which now troubled him was a feeling of dizziness in walking, and more especially on going downstairs. Mastication and deglutition had been very difficult after the attack, but were now tolerably good. The speech, which had been lost for a few days, was still affected, as the patient had lost the fluency of talk, and was sometimes obliged to stop in the middle of a sentence in search of a word. His face, which had at first been much affected, was still slightly distorted. He sometimes complained of palpitation of the heart; the tongue was clean and the appetite pretty good, but constipation was troublesome, so that he was obliged to take purgative medicines several times a week. He had for several years previous to the attack suffered much from pain in the loins, and had at times passed a good deal of gravel. There had been incontinence of urine and fæces for about six days after the attack; but the bladder and kidneys were now in their normal condition. The right arm was cold and stiff. He could not put the hand on the opposite shoulder, nor on the forehead, nor up the back. He could not write, nor cut his meat, but could manage with some exertion otherwise to feed and dress himself. The leg had almost entirely recovered. Faradó-muscular excitability was exactly the same in both sides of the body. The patient at first underwent a course of nitrate of silver, in one-sixth grain doses twice daily for six weeks, which improved digestion and defecation, and relieved the giddiness to some extent. He returned to town in February next, and as he still complained of hesitation in his speech, giddiness, and loss of power in the arm, I applied the constant current daily to the left hemisphere and cervical sympathetic, and to the nerves and muscles of the right arm. Within ten days he had almost entirely recovered the use of the limb, and only felt a slight pain on the top of the

shoulder when he threw his arm about. The anode was now applied for a few minutes continuatively to the painful spot, and after two such applications the pain was relieved. The treatment was altogether continued for a month, when the only troublesome symptom which still remained was inability of continued mental application.

The prognosis is not favourable in cases where the paralysed nerves and muscles show the phenomena of convulsibility and exhaustibility (Benedict). *Convulsibility* is that condition where the electro-muscular contractility, which on first applying either the faradic or galvanic current may have been normal or diminished, rises, as the current continues to act, more rapidly and to a greater height than it should do. On the contrary, there is *exhaustibility*, where the galvanic or faradic response of the nerves and muscles diminishes considerably after a short action, having been either normal, increased, or diminished at first. Both phenomena occur chiefly where paralysis is combined with idiotcy.

There are few cases of hemiplegia where there is not a slight amount of rigidity in some of the paralysed muscles; but in some instances the rigidity is so marked as to form the most prominent symptom. Twitchings of the fingers and toes are often connected with it; they occur especially at night, and interfere with sleep. In such cases the constant current should be used rather than faradisation, which latter may, however, be employed where an effective constant battery is not procurable. The following case shows that faradisation of the antagonists of the rigid muscles may do a certain amount of good in such conditions:—

Case 13.—In December 1858, J. M., aged 54, a carpenter, was under the care of Dr. Todd, in King's College Hospital. Four years ago he had had an attack of paralysis of the right side. The paralysed muscles had then soon assumed a state of rigidity, which had not undergone any considerable change since that time. When I first saw the patient he could walk with some

difficulty, but the right arm was perfectly useless, owing to rigidity of a number of muscles; viz. of the coracobrachial muscle, whereby the arm was adducted to the side, and of the biceps, by which the fore-arm was bent upon the arm. If forcible extension of the fore-arm was attempted, the biceps resisted the movement, but no pain was experienced during such forcible extension. The triceps was rigid, although much less so than the biceps; it was shown to be so when complete flexion of the fore-arm was attempted, so as to place the fingers on the acromion of the same side. The flexor muscles of the wrist and of the fingers were completely rigid; the hand was strongly flexed upon the fore-arm, and the fingers pressed against the palm of the hand, so that the patient was obliged to cut his nails very short, in order to prevent the skin from being irritated by them. The tendons of the flexors projected like tight strings beneath the skin. The patient, however, felt no pain if forcible extension of the wrist and of the fingers was attempted. The muscles were not much wasted, but faradic excitability was sluggish in the extensors, while the flexors of the fore-arm contracted readily under the influence of a gentle current. The muscles of the lower extremity were not nearly so rigid as those of the arm; some degree of contraction, however, existed in the hamstring muscles and the flexors of the toes; and in walking the patient was seen to drag the paralysed leg.

I thought that in this case it might be possible by faradisation to correct to some extent the disturbed balance between the different sets of muscles of the upper extremity; and this view was confirmed by the result of the treatment. I faradised the extensors of the fore-arm for some time, after which the tendons of the flexors, which had before projected like tight strings beneath the skin, became soft and flexible; and the patient was able to open his hand and stretch his fingers; but having been some time afterwards exposed to cold, the flexors again assumed a certain degree of rigidity. Unfortunately there was at that time no battery at King's College Hospital furnishing a continuous current, which I should have wished to apply to the rigid flexors, or the patient's condition might have been much more ameliorated. By further faradisation he again improved, but he left the hospital before permanent relief was afforded.

In such cases there is always a certain degree of subacute or chronic inflammatory irritation of that hemisphere of the

brain which is opposite to the paralysed side; and in some of them the continuous current applied to the head of the opposite side, to the sympathetic, and finally as cord-nerve-current, is of benefit, but which in most cases is only temporary. Nevertheless, we find that even in bad cases of hemiplegia with rigidity, perseverance in treatment is rewarded by a measure of success. Private patients are apt to lose hope if there is not a quick improvement; but from what I have seen in the out-patients of the hospital, whom I have been able to keep under observation for twelve or eighteen months consecutively, or even longer, I have come to the conclusion that few cases, however bad, are utterly incapable of amendment. The anatomical alterations which Messrs. Charcot and Cornil [1] have described as occurring in the motor nerves under these circumstances, are therefore probably not constant, or if they are, it must be supposed that they become less destructive of function under the influence of galvanisation.

Where hemiplegia is combined with total loss of language (aphasia) the prognosis is decidedly unfavourable. A slight impediment of speech (thickness, huskiness, &c.) often yields to treatment, but aphasia never.

Hemiplegia not unfrequently occurs in persons suffering from *tertiary syphilis*, and is then either owing to plugging of the vessels and softening, or to hæmorrhage. Iodide of potassium, which does so much good in other forms of neuro-syphilis, has, curiously enough, no effect on syphilitic hemiplegia; and if such patients do not recover by the reparative process of nature, we must have recourse to galvanisation or faradisation.

I think that the constant current acts beneficially in syphilitic hemiplegia, not so much by repairing the damage

[1] Comptes-rendus de la Société de Biologie. Paris, 1863.

done to individual blood-vessels by thrombosis, as by powerfully promoting collateral cerebral circulation, whereby the process of softening is prevented, the nutrition of already softened matter improved, and thus function gradually restored, either completely or partially. Potassic iodide cannot do this; it may be able to neutralise in, or eliminate from, the system all or most of the syphilitic poison, which causes the arterial disease that in its turn gives rise to softening and hemiplegia; but it cannot cure the softening, where this has proceeded to any considerable extent. This is the reason why the constant current must be looked upon as the necessary complement of potassic iodide in the treatment of most forms of neuro-syphilis.

CASE 14.—A carpenter, aged 42, was admitted as an out-patient at the Infirmary for Epilepsy and Paralysis on October 31, 1870; has had gonorrhœa several times, and had a hard chancre five years ago. There have been slight secondary symptoms off and on, affecting chiefly the fauces and the skin. Two years ago he suddenly lost his speech for about fifteen minutes; but, as he then completely regained it, nothing was thought about it at the time. Since then, however, he had again lost his speech on several occasions for an hour or two, but underwent no special treatment. In July last he began to have intermittent attacks of paralysis, which always affected the right side, but only lasted for a few hours at a time, after which he again felt quite well. After having had about a dozen such attacks, he at last, on August 30, had a real apoplectic seizure, accompanied with loss of speech and consciousness and total paralysis of the right side. His consciousness returned in about three hours, his speech to some extent at the end of the first week. The distortion of the face lasted only a day or two, and the leg began to improve after about a fortnight. The arm only improved to a slight extent during the first month, and has lately been quite stationary, so that he is thoroughly disabled from working.

Patient looks wretchedly out of health—in fact, thoroughly broken down. Tongue deviated to the left side and fissured. No affection of the cerebral nerves; but he complains of a constant aching pain at the back of the head and frequent flushes

of the face, which make him feel restless and miserable. Memory has been gradually getting worse; speech is thick and somewhat hesitating. The attention is apt to wander from one thing to another, and since the paralytic attack 'he has said and done foolish things.' Arm is to a great extent useless, through a semi-paralytic condition of the deltoid, serratus, trapezius, triceps, and extensor digitorum communis muscles. There is a slight contraction of the biceps and flexors of the hand and fingers, and a certain amount of pain at the insertion of the deltoid. Slight anæthesia and coldness of the whole upper extremity. Thigh and leg are weak; slight contraction of hamstring muscles. Digestion tolerably good; bowels regular; no disorder of the chest or genito-urinary organs. A small and tender node is on the left shin-bone, and at the right hip there is a rather large cicatrix from a syphilitic ulcer, which healed about two years ago. Ordered potass. iodidi, gr. v., ter die.

November 7.—No change in the patient's condition. He takes the iodide well; it was, therefore, increased to ten grains thrice daily.

14.—No change in the paralysis; no iodism. Fifteen grains ter die.

21.—Same report. Scruple doses of potassic iodide.

28.—Slight ephipora and coryza; no improvement in paralysis; on the contrary, the contractions both in the arm and leg are increasing. Continue iodide.

December 5.—Contractions still increasing; iodism is getting troublesome. The iodide was therefore given up, and an indifferent mixture substituted for it; at the same time galvanisation of the cervical sympathetic and of the suffering nerves of the arm and leg was ordered three times a week.

12.—First application of the constant current to the sympathetic removed the pain from the back of the head; arm and leg feel a little stronger; immediately after the application the paralysed side feels warmer than the healthy one.

January 30, 1871.—Patient has had seventeen applications of the constant current. He is able to use arm and leg so well that he wishes to be discharged, as he feels able to return to his work. Has not attended since.

In paralysis owing to tumour or abscess of the brain, or any other severe structural lesion, no form of electricity can

do good. But where it seems to occur in consequence of exhaustion and slight effusion, without any serious structural change, the continuous current may be used, and the effect is then generally immediate. The following case is one of this class :—

CASE 15.—A merchant, aged 52, married, had been in a low state of health for some years past in consequence of much anxiety and trouble, but had not suffered from any serious illness. He was sitting quietly at home, on July 20, 1867, writing a letter, when he suddenly felt faint and giddy, the pen dropped out of his hand, and he completely lost the use of the right arm. He did not lose his speech and consciousness, nor the use of the leg, nor was the face distorted. A friend who happened to be present advised him to put his hand into boiling water, which he did, and blistered it most severely with it. As the scalding of the arm and hand produced no effect, a cold douche was next applied to it, and the wrist was then a good deal knocked about, in order to get the life back into it (!) As none of these violent measures had the least effect, the patient consulted me two days afterwards, when I found complete paralysis of the fore-arm and hand, and nearly complete anæsthesia of the hand and fingers. I applied a current of twenty cells to the left hemisphere for one minute, after which the patient lifted his wrist and moved the fingers to a slight extent. I did not use any peripheral galvanisation. Two days afterwards he came again, when I found that the improvement had continued, but not made further progress. I then again resorted to cerebral galvanisation, with the effect that a little more action in the hand became manifest. But as it was still weak, I now combined peripheral galvanisation of the radial and median nerve with it. The effect of this was apparently even greater than that of the cerebral application, as the patient could grasp my hand firmly afterwards, and dress himself without assistance. Another application of galvanism on the following day completely restored the use of the hand and fingers.

2. *Spinal Paralysis.*—By this is meant real paralysis of motion, and not want of co-ordination of movements, which latter occurs in tabes dorsalis or ataxy. Spinal paralysis is due either to primary lesions of the antero-lateral columns

and the grey matter, or it comes on from affections of the spinal meninges and the vertebræ. If the paralysing lesion be seated in the lumbar portion of the cord, there is paralysis of the lower extremities (paraplegia) and of the muscles of the pelvis. Where the dorsal portion is affected, the abdominal and lumbar muscles suffer likewise, respiration is impeded, and there may be tympanites, priapism and paralysis of the sphincters. Finally, if the cervical portion be diseased, the upper extremities are also paralysed, respiration suffers more considerably, and deglutition becomes imperfect; but the intellect and the nerves of special sense remain in their normal condition. In cases of this kind the excitability of the muscles is diminished in exact proportion to the degree in which their nutrition is impaired; and it may at last entirely disappear. Anæsthesia is more complete and permanent in spinal than in cerebral paralysis; nutrition is therefore more seriously impaired, and there is great disposition to decubitus. Spinal hemiplegia is very rare, and has as yet not become the object of electrical treatment.

Whether galvanisation is likely to do good or not in spinal paralysis, depends chiefly upon the cause and duration of the disease, and upon the age and constitution of the patient. Where the paralysis is caused by tumours pressing on the spinal cord, or by caries of the vertebræ, or when it has come on after fractures or dislocations, or if the substance of the cord is actually destroyed by hæmorrhage, inflammation, or softening, the galvanic current may relieve certain symptoms of the affection, but cannot have any curative effects.

There are, however, many cases of spinal paralysis which come on after acute diseases, such as typhoid fever, suppression of habitual hæmorrhage, or after a very abundant hæmorrhage, principally post-partum; after cold, convulsions, over-exertion, a fall on the back, and in consequence of general anæmia. In these we have to do either with

hyperæmia or with anæmia of the cord; and it is probable that anæmia and atrophy is the ultimate result of all. In cases of this kind the constant current should be used, and its employment is almost always followed by satisfactory results. *Cæteris paribus*, young patients and recent cases are more likely to get well than the reverse.

CASE 16.—T. B., aged 35, a surveyor, had, with the exception of gonorrhœa, never been ill until six months ago, when he was unusually overtaxed with work, and was constantly exposed to the influence of damp and cold. So gradual was the loss of power that came over him, that he was not the first to notice it, but was told by his friends that he walked lame. Soon afterwards, however, he felt so weak that he could not walk without the aid of a stick. His feet used to perspire a good deal before he began to suffer in this way, but had not done so after he had become lame. In the region of the tenth dorsal vertebra the back was painful to pressure, and a hot sponge applied there produced a peculiarly unpleasant sensation, different from that which was felt on other parts of the back. The patient had at first perceived 'pins and needles' in the lower extremities, which was, after a time, succeeded by a feeling of numbness, so that in walking he did not feel the ground. When standing in the dark, or with his eyes closed, he at once began to stagger. Going downstairs was very difficult for him. The skin was dry, cold, and flabby. I examined it by the aid of the æsthesiometer, and found a great diminution of sensibility all over the lower part of the back, the epigastrium, and the lower extremities; but there was no complete anæsthesia. The muscles of the abdomen and of the lower extremities were somewhat wasted, and sluggish in their response to the galvanic and faradic stimulus. The patient suffered from costiveness and a feeling of pressure and tightness in the epigastrium, and was obliged to use great exertions for relieving the bladder. The urine was apt to turn alkaline in a short time, but otherwise healthy. The patient had sometimes involuntary emissions of fæces and urine. He had taken much medicine, especially strychnia, bichloride of mercury, and iodide of potassium, but without any benefit.

Galvanisation of the back and the feet, and faradisation of the muscles of the abdomen and of the lower extremities, was now resorted to. After a fortnight's treatment the patient felt a good

deal better. He had more control over his legs, was better able to hold and pass his urine, and sensation was more distinct everywhere. He remained under my care for nearly six weeks, getting gradually stronger, and being able to walk a short distance without the aid of a stick. A longer treatment would probably have produced even more decisive results.

CASE 17.—A commercial traveller, aged 38, consulted me in October 1864 for weakness in the back and loss of power in the lower extremities. He began to suffer in March of the same year, after unusually hard work and great fatigues; and had gradually become worse from that time. At first he felt a sensation of 'pins and needles' in the feet, but this had now been succeeded by numbness. His gait was tottering, and he could only walk by the aid of two sticks. There was a high degree of anæsthesia in the back from the sixth dorsal vertebra downwards, and also in both thighs and legs, so that the application of a very powerful galvanic current was only just felt as a slight tingling sensation. The patient also suffered from costiveness and difficulty of micturition. There was no ataxy. I applied the continuous current twice a week for two months, at the end of which time the patient could walk without a stick, had lost the feeling of numbness in the feet, and the anæsthesia of the back had so far yielded that the application of forty cells of Daniell's battery was all he could comfortably bear, while at first the current of a hundred cells had appeared to him 'like nothing.' From beginning with the latter number, I gradually came down to fifteen cells, which were distinctly felt at the end of the treatment.

The following is one of Meyer's cases[1]:—

A Prussian officer, aged 38, who was much exposed to cold and heat alternately, being employed in the gun-factory at Spandau, first perceived in 1862 a sort of unsteadiness in his legs, which was followed by a feeling of cold and numbness in the whole left side of the body. These sensations gradually disappeared, but were succeeded by progressive weakness in the left thigh, reflectory movements in both legs, wasting of the left glutæi and muscles of the left thigh, and a feeling of weight in the lumbar

[1] Die Elektricität, etc. p. 328.

spine. The patient improved under treatment; but in October 1867, on getting out of a cab, fell down, and could not get up by himself. From that time the lameness of the leg increased very much; going downstairs was very difficult, and the muscles of the thigh wasted away rapidly. There was pain on pressure on the lumbar spine. Meyer applied the positive pole to the painful spot of the spine, and the negative to the left crural plexus. After nine such applications the nutrition of the leg was improved, the lameness less, going upstairs and downstairs was easy, and the patient could walk for some miles without fatigue.

Dr. Hitzig[1] has cured a similar case :—

A sergeant-major of the Prussian Guards, aged 33, fell with his horse in March 1865, and came down on the bottom of his back. He felt pain there, but was able to remain in active service until May, when he had pleurisy. He was convalescent in July, but from that time the pain in the back increased; there was also pain in the legs and extreme sensibility to touch. He had 'pins and needles' in the feet, and felt the ground soft on walking. There were involuntary muscular twitches, and the patient became very lame; emissions of semen took place three or four times a week. He could neither walk nor stand with closed eyes, or in the dark, and was obliged, when he walked, to do so in a stooping position, as in walking erect he felt dizzy, and the pain in the back increased. Nitrate of silver and iodide of potassium had no effect. He slept badly, and had scarcely any appetite. After eight applications of the continuous current to the spine continuatively, he slept well; there was only little pain, and the legs felt easier. The crural nerves were now likewise galvanised intermittently, and with such good effect that the numbness in the feet disappeared, and he could stand with closed eyes for fifteen seconds without staggering. After six weeks all symptoms had yielded to the galvanic treatment, with the exception of a slight pain in a few of the intervertebral spaces. The patient had two relapses, after considerable exertions and cold, but which yielded to the same treatment.

Syphilitic paraplegia sometimes comes on very suddenly, while in other cases its invasion is more gradual. In recent

[1] Virchow's Archiv, 1867, vol. xl.

cases large doses of iodide of potassium are sufficient for a cure, while in cases of long standing this drug produces little, if any, benefit. In such cases we must use the constant current, either with or without potassic iodide.

I subjoin some cases which will illustrate these propositions :—

CASE 18.—A paper-stainer, aged 32, had a chancre three years ago, and secondary symptoms affecting the skin and fauces at intervals. Was admitted as an out-patient in the Infirmary for Epilepsy and Paralysis on May 17, 1869, when he was suffering from complete paraplegia, which had come on rather suddenly about ten days previously. He had been apparently well, when he began one evening to complain of sensations of 'pins and needles' in the feet; next morning he felt numbness in the lower extremities, and staggered in walking. As the day wore on he got worse, and towards evening was perfectly helpless. He was carried into the consulting-room of the Infirmary, being quite unable to move his legs. There was complete anæsthesia from the waist downwards; the bladder and rectum were not affected. The paralysed muscles responded well to both the induced and continuous current. The legs were much colder than the arms. There was a slight degree of ptosis of the left eyelid, and incomplete palsy of the rectus externus of the same eye. This patient emitted a most disagreeable smell from the surface of his body, and this was quite as bad when the patient's back was turned as when one faced him. It was not the peculiar 'poor-man's smell' which is so often noticed in out-patients of hospitals, and which arises chiefly from filthy shirts and underclothing, nor was it the well-known unpleasant smell which is owing to foulness of the stomach; but it was a smell *sui generis*. Ordered gr. xv. of potass. iod. thrice daily.

May 24.—Patient reports himself somewhat better; the numbness is not so great, and he can move his legs a little when he is sitting on a chair. Gr. xx. of potass. iod. thrice daily.

31.—Patient takes the iodide well. Can stand when supported by one person's arm; moves his legs more freely.

August 2.—The iodide has been continued without ever disagreeing. He can now walk pretty well for about a mile with the aid of a stick; anæsthesia completely gone.

October 18.—Patient presents himself, apparently quite well. The smell has completely disappeared. Discharged.

This is one of a class of cases showing that *in recent cases of syphilitic paraplegia large doses of potassic iodide are sufficient for a cure.*

Case 19.—*Syphilitic Paraplegia of Three Years' Duration.*

A cabinet-maker, aged 39, married, of wretched appearance and sallow complexion, applied at the Infirmary on February 27, 1871, complaining of inability to walk. It appeared that he had long suffered from shooting pains in the head and limbs, a feeling of faintness, and weak sight. A twelvemonth ago he occasionally lost his sight completely for a few hours, after which it would return. He is deaf in the right ear. At the commencement of 1868 he began to suffer from 'pins and needles' in the feet, and gradually lost power over the lower extremities. There had never been complete paralysis; the patient could turn in bed, and walk slowly and in a jerky manner, with the aid of a stick and another person's arm. He cannot stand with his eyes closed for more than a few seconds, finds it difficult to put his foot on a chair, and has scarcely any command over the ankle-joint. There is difficulty of micturition and defecation. The patient, who seems to be a truthful and religious man, denies having had any sexual relations out of wedlock, and says he had never had any sore on the penis. His wife, who accompanies him, has the appearance and bearing of a woman of the town, and has a copper-coloured eruption on the forehead and neck, and swollen cervical glands. On being questioned, she complains of a 'nasty discharge from the womb,' which she has had for a long time. Patient was ordered potassic iodide, in ten-grain doses ter die, and a table-spoonful of cod-liver oil twice a day.

March 6.—Feels rather better in himself, but is still very poorly on his feet. Dose of potassic iodide increased to fifteen grains.

13.—Much the same as before. To take twenty grains of the iodic salt thrice daily.

April 3.—Symptoms of iodism; the dose is reduced to ten grains ter die. There being no improvement, the constant galvanic current was ordered to be applied to the spine three times a week.

June 26.—Patient, who lives at a considerable distance from the Infirmary, has only been able to attend once a week for the

application of galvanism. The general aspect of the case remains unchanged, although considerable doses of the iodic salt have been taken for four months. Patient ceased attendance.

This is one of a class of cases showing that *in syphilitic paraplegia of long standing, iodide of potassium produces little, if any, benefit.*

Case 20.—Neuro-Syphilis of Nineteen Years' Standing.

A carpenter, aged 54, applied at the Infirmary on April 1, 1870. He had had a chancre in 1851, followed by rash and sore throat. Three months had scarcely elapsed after the primary affection when cerebral symptoms began to make their appearance. He lost his memory to a great extent, had difficulty in speaking, and gradually became very weak in his legs. He applied at a general hospital, and, after two months' treatment, had apparently quite recovered. Two years afterwards he had several convulsive fits, in which he lost his consciousness; and some years later he was out of his mind for a few days, and very violent. He is a total abstainer, but occasionally feels as if he were drunk and would fall; but he can by an effort rouse himself, 'without going off.' His speech is now tolerably distinct, although articulation seems troublesome; his memory is better than it was ten years ago; he feels no diminution of his intellectual capacity; he has slight ptosis of the left eyelid, and numbness in the third and little finger of the right hand. He applied at the Infirmary chiefly on account of his walking so badly—indeed, he walked like a man suffering from locomotor ataxy. As it appeared that the man had already taken large quantities of mercury and potassic iodide, no medicine was given. The constant current was applied continuously to the spine, and intermittently to the nerves of the legs. After twenty applications the patient walked very much better than before, and ceased attendance.

This is one of a class of cases showing that *in syphilitic paraplegia of long standing the constant galvanic current is an excellent remedy, which should always be employed where iodide of potassium fails to do good.*

There is a peculiar kind of paralysis which some observers believe to be owing to disease of the cervical sympathetic, but which is more probably owing to spinal anæmia. That

this kind of paralysis is cured by the proceeding known as 'galvanisation of the sympathetic,' is no proof that it is really caused by disease of the sympathetic system of nerves; for in the proceeding employed, the cervical portion of the spinal cord is likewise put under the influence of the current. Dr. Drissen, of Berlin, has recorded the following case of this kind:—

A sculptor, aged 35, served in the Prussian campaign of 1866. Ever since July of that year he had suffered a good deal in his arms. When he came under observation, both arms were wasted and as cold as ice; the hands were anæsthetic and anæmic, like those of a dead body; no blood flowed when a needle was deeply stuck into them and taken out; the movements were difficult and powerless. The lower extremities were in much the same condition, but not quite so bad. Diaphoretics of all kinds had been used for producing perspiration, but without success. Dr. Drissen directed the continuous current to the cervical sympathetic, and during the second application profuse perspiration occurred, more especially in the fingers, while the hands became red; diplegic contractions of the upper and lower extremities occurred at the same time. The temperature of the limbs rose considerably, and the motive power of the extremities was simultaneously increased. After twelve applications the patient had so far recovered that he could return to the active exercise of his profession. In this case no peripheral galvanisation had been used, nor had any medicine been given.

The same physician has treated a youth, aged 18, who perceived, after lifting a heavy weight, a sensation of heaviness and stiffness in the arms, which increased chiefly in the right side, and prevented him from writing. Neuralgic pains occurred in the sphere of the median and ulnar nerve. Peripheral galvanisation was resorted to for six weeks; but as the symptoms were rather aggravated than otherwise, the patient was taken to Dr. Drissen, who applied the positive pole to the left superior cervical ganglion, and the negative to the right transverse processes of the second to sixth dorsal vertebræ. The right arm felt warm after the first application; the second produced strong contractions in the biceps; and the third in the deltoid. After this treatment had been continued for two months, the patient was perfectly well.

Meyer[1] has seen good results in a similar case :—

A butler, aged 46, had for some years past suffered from occasional spasmodic sensations in the throat, which rendered deglutition impossible; sensations of numbness and tightness in the legs, the spine, and the chest were also complained of; sometimes there was general tremor and convulsive movements of the heels, knees, and the neck. Standing gradually became difficult and walking impossible. The right side of the neck was much swollen, hard, and extremely sensitive, especially on a point corresponding to the superior cervical ganglion. Meyer thought that the tumour, by pressing on the cervical sympathetic, caused all these symptoms, and therefore resorted to galvanisation of the same. No other treatment was used. Within six months the patient had so far recovered that he could walk several miles at a time. He was under treatment altogether for about eighteen months, the galvanism having been applied 270 times. In 1867 he was perfectly well.

3. *Hysterical Paralysis.*—This form of paralysis, which occurs generally in consequence of mental shock and painful emotions, in girls and women whose sensibility is unusually acute, may attack a few muscles only, or an entire limb, or the whole body. It is brought on either suddenly, or creeps on gradually and unawares. It frequently assumes the form of paraplegia, the recti of the thighs being most affected, but hysterical hemiplegia is by no means uncommon. Hysterical paralysis is altogether a functional disorder, and in no way connected with structural lesions in the nervous centres, the peripheral nerves, or the muscles. It is seldom the only symptom of hysteria in a patient, but is generally accompanied by globus, hysterical pains, anæsthesia of the skin, muscles and bones, spasms, and disordered menstruation. The course and termination of hysterical paralysis are sometimes whimsical. Some cases get well in an almost incredibly short time, without any treatment, and sometimes make the

[1] Loc. cit. p. 340.

fortune of charlatans, while others resist for years a variety of energetic therapeutical efforts. On the whole, galvanisation of the spinal cord, producing anelectrotonus where there is a high degree of excitability, and catelectrotonus where there is depression, is the best treatment; but where no apparatus furnishing a continuous current can be procured, faradisation of the skin of the paralysed limbs by fine wire-brushes should be resorted to. Faradisation of the paralysed muscles by moistened conductors has usually only little effect, as it is chiefly upon sensibility, and not so much on contractility, that we have to act in this condition. Some cases are cured by the use of faradisation and galvanisation alternately.

CASE 21.—A girl, aged 19, living at Kilburn, became an outpatient at the Samaritan Free Hospital in September 1864, and was sent to me by Dr. Savage. She had always been in indifferent health, and during the last three years had gradually lost the power over her arms and legs, to such an extent that she was scarcely able to walk even when supported, and entirely incapacitated from doing any work whatever. The cause of the affection was said to be due to 'some trouble' she had had. She first menstruated at 15 years of age, but was always irregular, the discharge being very pale and scanty. Sixteen months ago the catamenia ceased altogether, and from that time she became nearly idiotic. She was very listless when I first saw her, had a vacant look, and considerable dilatation of both pupils, more especially of the left one. The left iris was scarcely at all influenced even by strong light. The voice was almost entirely gone; she could only speak in a faint whisper. She was frequently troubled by pain in the head and the back. Her hands and feet were always quite cold. She complained of sickness in the morning, total want of appetite, and constipated bowels. She was always worse after emotions, and had frequently had hysterical fits. The muscles were very badly nourished, but contracted tolerably well under the influence of the electromagnetic current. There was anæsthesia of the whole left side, including the conjunctiva. On the right side the loss of sensation was not so marked as on the left; but the prick of a

pin was only felt as if it were a touch by some blunt instrument. I applied an inverse current of from forty to fifty cells to the spine, continuatively, twice a week. After six weeks the patient was so much improved that she could walk three miles at a time without support; she could dress and feed herself; was able to do heavy work about the house, and had always warm hands and feet. The voice had returned, the bowels acted regularly, and she was cheerful, and took an interest in everything relating to her affairs. The pupils also gradually recovered their normal size; and the catamenia re-appeared on December 27, and continued from that time at regular intervals. The patient has several times called upon me within the last two or three years, and informed me that she has continued in perfect health ever since.

CASE 22.—A lady, aged 30, unmarried, was said to have suffered from congestion of the spine eighteen months before she came under my care (May 1868). She had not been able to move from her bed or sofa since then, and had lost flesh to a great extent. When she endeavoured to sit up or walk, she felt so sick that she was obliged to lie down again. There was a sensation of numbness in both lower extremities, and in the back from the sixth dorsal vertebra downwards, but no complete anæsthesia. Both legs were habitually cold; the appetite was excellent, but the bowels habitually confined, and the catamenia rather too abundant. The cause of the affection was a series of great mental emotions the patient had undergone. Faradisation and galvanisation were alternately used with the effect that after six weeks' treatment she could walk half a mile, without feeling sick or tired. The treatment was continued in the country, and when I last heard of her (April 1869) she was again quite strong and well.

CASE 23.—*Hysterical Paralysis, Neuralgia, and Loss of Voice.*

M. K., aged 40, a needlewoman, of feeble constitution, had for a long time suffered from neuralgia in the right arm, and also from want of power in the muscles, so that she was unable to work. The cause of the affection was trouble and anxiety. She became an out-patient at the Samaritan Free Hospital, under the care of Dr. Henry G. Wright, who sent her to me. After four

operations, in which I faradised the weakened muscles and the skin, she was greatly improved; but when she came to me next time, she had lost her voice. I thereupon directed the faradic stimulus to the larynx, with the effect that the voice returned at once. By further treatment the patient got quite well.

4. *Lead-Palsy.*—In this disease—which affects chiefly painters and compositors, but may also be caused by drinking water, beer or wine, which has become impregnated with lead, or by taking snuff which has been packed in lead-foil, or by using cosmetics containing lead, and in various other manners—the internal administration of iodide of potassium is the best means of removing the lead from the system; but this alone is seldom sufficient for curing the palsy, which requires a special treatment.

Lead-palsy attacks with preference the upper extremities. M. Tanquerel des Planches saw, amongst 113 cases of this affection, 93 cases of palsy of the arms, 14 of the lower extremities, and 6 of general paralysis. Certain sets of muscles are more liable toit than others. The extensors of the right fore-arm are the first to suffer; the wrist drops and cannot be extended; the power of extension of the first phalanges of the fingers is also gone; but the motion of the two last phalanges is not impaired, as the interossei scarcely, if ever, participate in the disease. The muscles waste away, the back of the fore-arm appears hollow, the thenar eminence flattened, and the triceps and deltoid thin. The electric contractility of these muscles is either totally gone or considerably diminished; but sensibility is generally preserved.

Lead-palsy is by many observers believed to be a spinal affection, but chemical analysis has not shown that lead is chiefly attracted by the nervous centres. The rapid wasting of the affected muscles, and the thorough alterations of their electric excitability, lead us rather to assume that lead-palsy is peripheral affection. Lead, if frequently handled, is

absorbed by the skin, more especially of the right hand, and it is probable that by the astringent effects of the metal the blood-vessels of the limb are so much constricted as no longer to afford sufficient nourishment to the motor nerves and muscles.

The best rule for treatment is that, where faradic contractility is entirely gone, the constant current should be used, producing catelectrotonus of the suffering nerves, and stimulation of the muscles by intermittent applications, with voltaic alternatives. Where no constant battery can be procured, faradisation must be resorted to; but this treatment is much more tedious than, and not nearly so effective as, that by galvanisation. Where faradic excitability is only diminished but not lost, faradisation is always useful; but even in such cases galvanisation is preferable.

M. Eulenburg has related a case in which faradic contractility was completely lost, but galvanic excitability preserved and even increased; and a good therapeutical result was obtained without restoration of faradic, or diminution of galvanic contractility. Eulenburg has, however, seen after a galvanic treatment, not only recovery of voluntary power, but also of faradic contractility. In one case he observed diplegic contractions, not only with the arrangement mentioned by Remak, but also in crossed or unilateral arrangement of the electrodes, on any part of the trunk, with continuative or intermittent application of from ten to twenty cells. These contractions appeared almost immediately on closing the circuit; where the poles were crossed they were stronger, and came on more rapidly in the arm corresponding to the negative pole; but on increasing the power of the current, they appeared in the other arm, and even in the face, and one or both lower extremities. They commenced with movements of extension and adduction of the fingers, elevation and adduction of the hand and the fore-arm, and finally the whole arm was elevated and adducted towards the thorax. Where the current acted continuatively, these movements partook rather of the character of a gradually increasing tetanic contraction; while, if it was intermittent, the contractions were jerking and convulsive.

Dr. Walter G. Smith[1] has recorded the following case :—

In May 1866 a robust man (William S.), aged 56, was taken into Sir P. Dun's Hospital. For the last forty years he had been engaged in painting, papering, or colour-grinding, and had had colic twice before his present illness, which dates back nearly two months. Both arms, and especially the right, were partially paralysed, but there was not complete drop-wrist, and no turning in of the hand. On May 12 Dr. Smith commenced faradisation, and readily obtained contractions without causing pain. Very soon improvement was perceptible, and the atrophied muscles of the right thumb resumed their normal bulk and firmness, and his writing became legible. This progressive improvement continued, and in about three weeks he left hospital by his own wish, having nearly recovered the full use of his hands. He was cautioned against resuming work too soon, but was obliged to do so, and in October 1867 he applied for admission into the Adelaide Hospital. A fortnight after leaving Sir P. Dun's Hospital he had resumed work as usual, and improved steadily while so engaged, till about three weeks ago he began to suffer from pain and tenderness along the tibiæ, and his general health declined. Soon the ring and little fingers of the right hand lost their strength, and within the last week the debility and muscular wasting had rapidly increased. Tremors in the muscles of the legs had come on, and spasmodic startings were observable in the lips, eyebrows, &c., while the muscles generally were easily excited to reflex action. No colicky symptoms were present. A moderately tight ligature applied on either thigh completely checked the tremulous movements in that limb, and on tickling the skin of the leg no reflex movements occurred in it, but powerful ones in the opposite lower extremity.

Muscular faradisation was commenced on November 13, and regularly continued. The atrophied muscles soon showed evidence of increased nutrition, and in one month he left the hospital, having nearly regained the full use of his fingers.

Dr. Anstie[2] has successfully treated a case of lead-palsy, in which almost the whole of the muscles of the right hand, fore-arm, arm and shoulder, were wasted to an extreme degree.

[1] Dublin Quarterly Journal of Medical Science, August 1869.
[2] Transactions of the Clinical Society of London, vol. iii. 1870.

The disease was confined to the limb, probably because the poison had been taken in only through the right hand, which constantly dabbled in the lead paints used by the patient in his trade. The constant current was employed daily for eight weeks. Faradic excitability then returned, and, in another month of treatment by faradisation, both the power and the bulk of the muscles were almost completely restored.

5. *Rheumatic Paralysis.*—Paralysis of certain muscles or sets of muscles is not unfrequently induced by rheumatism. The angler, the huntsman, and others who by pleasure or necessity are much exposed to damp and cold, are chiefly liable to this kind of palsy, which affects with preference the muscles of the lower extremities, thus giving rise to incomplete paraplegia, which is frequently mistaken for a symptom of disease of the spinal cord. The extensor muscles of the fore-arm, which are animated by the radial nerve, are also often subjected to rheumatic paralysis. Next in frequency ranks paralysis of the muscles of the eyes, the portio dura, and the deltoid and trapezius. The interossei and lumbrical muscles are also liable to rheumatic palsy. I have observed this latter affection chiefly in young women suffering from anæmia and defective circulation. The first symptom is a feeling of numbness and pain in the fingers, and the movements become difficult and troublesome. On faradising the interossei, their excitability appears impaired. In this stage it is easy to arrest the disease by a short faradic treatment; but if nothing be done for it, the muscles may in time become atrophied; the interosseous spaces then appear hollow, the circulation is impaired, the hand thin and cold, the fingers can be but slightly removed from one another, and the extension of the two last phalanges is impossible; numbness and stiffness increase, and at last the hand becomes quite useless.

The invasion of rheumatic paralysis is sometimes sudden, in other cases gradual. It is sometimes the consequence of rheumatic fever. It may begin with pain in a set of muscles, whereby motion is rendered difficult or impossible; and when the pain is gone, the immobility still continues; in other cases no pain, but only numbness, is complained of. Where the invasion has been sudden, and pain is felt in the paralysed muscles, the electric stimulation of the muscles is likewise painful; but when the disease has come on gradually, galvanism and faradism excite very little sensation.

There is no kind of paralysis in which the therapeutical effects of faradisation are so striking as in rheumatic paralysis, in which affection it cannot be replaced by any purely medicinal treatment. This applies also to protracted and severe cases which have resisted a variety of energetic therapeutical measures. M. Guitard has related the case of a patient who had suffered for three years from rheumatic paralysis; there was general emaciation and immobility; the head dropped on the chest, the thighs were flexed upon the abdomen, the legs upon the thighs. Faradisation was used for a month, and after that time the head could be held erect and the legs be moved into and out of bed. The faradic treatment was then discontinued for some time, whereupon the patient relapsed into nearly his previous state; it was then recommenced, and at the end of six weeks an almost total recovery had taken place.

I am convinced that every case of rheumatic paralysis can be cured by faradisation, provided that the muscular tissue has not yet been too extensively atrophied, and the treatment is not too soon discontinued. In cases of muscular atrophy resulting from rheumatic paralysis, galvanisation is likewise of great service.

CASE 24.—*Rheumatic Paralysis of the Fore-arm and Hand.*

Mrs. G., aged 51, was sent to me by Dr. Hyde Salter, in Jan. 1862. Three months before, she had suffered from a severe attack of rheumatic fever, nearly all the joints having been affected. As soon as she was able to move about again, she went into the country, where her general health much improved. Her

right arm and hand, however, remained painful and useless, and she was therefore advised to try faradisation. On examining the fore-arm and the hand with the æsthesiometer, I found that the sense of touch was considerably impaired. The muscles were wasted, more especially the flexors and the interossei and lumbricals; and on applying the faradic current to these muscles individually, it appeared that their sensibility, as well as their contractile power, were very nearly gone. The hand had lost its natural shape, and resembled a bird's claw—a configuration of the hand which is always associated with loss of power in the interossei and lumbrical muscles, and renders it entirely useless. The pain was greatest at night, and chiefly felt in the fingers. The general health of the patient was tolerably good, but she was very thin, and suffered greatly from despondency. I used faradisatian of the skin for the cure of the pain, and of the suffering muscles for restoring them to their normal nutrition and function. After two operations the motor power of the fingers was much increased: the muscles responded more readily to the faradic stimulus, and the æsthesiometer showed an improvement in the sense of touch. The pain, although not entirely gone, was much diminished. After a fortnight's treatment, the patient attending every other day, she was able to cut her own meat and to do some housework, and in a month she could do needlework for three hours consecutively without feeling pain or fatigue. There was then no longer any difference in the sense of touch in the right and left arm, the bulk of the muscles was much increased, and the hand had resumed its normal shape. This result was all the more satisfactory, as the age and general weakness of the patient were not in favour of a rapid cure.

Case 25.—An unmarried lady, aged 28, consulted me on March 11, 1873, for loss of power in the left arm, which had come on quite suddenly four months ago, after she had slept in a damp bed. There was at first a good deal of pain in the arm, but lately the pain had left her and given place to a feeling of stiffness, which was combined with a knotted condition of the skin and cellular tissue and wasting of the muscles. The muscles chiefly affected were the trapezius, serratus, deltoid, and a number of muscles animated by the radial nerve. The flexors of the fingers did not suffer, for the patient could use her hand for taking hold of things, but she could not move the arm either at a

right angle to the body, or backwards, or upwards, nor could she place the hand on the opposite shoulder, which showed paralysis of the pectoralis major. Both faradic and galvanic excitability were diminished. Catelectrotonus was produced in the suffering nerves and muscles, combined with intermittent stimulation and voltaic alternatives. Under the influence of catelectrotonus the patient was able, almost immediately after the current had begun to act, to move her arm better in all directions. She gradually recovered the power of the arm, by fourteen applications of the current, and went to the country on April 1. The arm then felt still rather stiff, and it required an effort to make certain movements; yet she could do everything with it that she wanted. A few more applications would probably have entirely restored the flexibility of the limb.

6. *Reflex Paralysis.*—The existence of this particular form of paralysis has recently been questioned by many of the best observers, and there can be no doubt that many cases which were formerly claimed as such of reflex, sympathetic, or neurolytic paralysis are really owing to structural disease of the spinal cord, which may escape examination by the naked eye, but is revealed by microscopical and chemical investigation. The majority of cases of reflex paralysis were such as paraplegia connected with disease of the kidneys, bladder, prostate and urethra, and the womb and ovaries. The remote organs were believed to transmit their irritation to the cord, and thence to the motor nerves of the lower extremities, thus causing paraplegia; but the latter was in reality a sign of disease of the cord itself. Sir William Gull has described cases where so-called reflex paraplegia followed upon gleet, stricture of the urethra, cystitis and nephritis, and where the post-mortem examination showed that there was likewise acute meningitis, softening and atrophy, or fatty degeneration of the anterior columns of the cord. Nevertheless, we believe, after duly weighing everything that has been said against reflex paralysis, that there will still be found cases which we may fairly claim as belonging to this

class. We find the physiological basis for this view in the facts which have lately been discovered concerning the inhibitory system of nerves. The experiments of Setschenow, Goltz, Löwig, and others—into which space forbids us to enter—have shown that we may temporarily suppress the function of the cord by producing intense irritation of certain peripheral nerves. In rabbits, in which the kidneys, womb, or intestinal mucous membrane is squeezed, sudden paralysis of the hind legs comes on, with abolished reflex excitability; and as soon as the squeeze is relaxed, the paralysis disappears. With regard to pathology, we find cases on record where the sudden recovery of function after the removal of peripheral irritation leaves no doubt about the nature of the disease. Landry has described a case of paraplegia from flexion of the womb; when the flexion was remedied, the palsy disappeared. Again, Rosenthal has seen a case of paresis of both lower extremities, which disappeared on a needle being extracted from the vagina.

Where we have reason to suppose a case to be one of reflex paralysis, and where, after duly removing any irritation which may in our opinion inhibit the function of motion, yet the paralysis remains, faradisation or galvanisation are by far the best therapeutical measures to be used. Again, in some cases, faradisation or galvanisation may remove the irritation, and thus exercise a curative action. These propositions will be best understood if illustrated by a few cases.

Case 26.—Mrs. D., aged 42, pricked the fore-finger of her left hand with a needle. This induced considerable pain, of which she did not at first take much notice; but as the finger soon became much inflamed, she applied for medical advice. Notwithstanding the treatment she underwent, the inflammation increased, gangrene ensued, and at last amputation of the finger became necessary. This operation was performed by Mr. Spencer Wells on December 23, 1858. Three months elapsed before the stump was healed, as at first the pus was of a very bad character;

and the secretion only improved after repeated cauterisations with nitrate of silver. When the cicatrix had at last been formed, it appeared that the patient had entirely lost the use of her hand, and Mr. Wells then sent her to me. When I first saw her, the fingers were extended and quite stiff; flexion and lateral movements were impossible. The fore-arm could only with difficulty be bent, and every movement of it was painful. Numbness was felt in all the fingers, and pain in the elbow was complained of. The stump, which had a livid colour, was extremely sensitive, and at the slightest touch of it the patient almost fainted Besides this, she had that peculiar symptom which is by no means rare in persons who have undergone an amputation; that is, she felt pain in the removed part, which increased towards evening. Otherwise she was in fair health, with the exception, however, that she had three years before, after a difficult labour, lost the catamenia, and, in consequence of this, she suffered from headache for a few days every month. I directed a primary faradic current to the left arm, the positive pole being alternately applied to the trunks of the median and ulnar nerves. Intramuscular faradisation of the interossei and lumbricals was also performed. Immediately after the first application, the patient was able to bend the second and third phalanges of the fingers; and after three more applications she was no longer troubled with pain in the removed finger. After the ninth operation, the catamenia reappeared. The restoration of the mobility of the first phalanges of the fingers required a somewhat longer treatment, as in them the affection was very obstinate; but after some weeks this was also attained. At the same time the stump had assumed a much healthier colour; it was firmer, and not so sensitive to touch as before. The catamenia continued afterwards at regular intervals.

CASE 27.—M. W., a married woman, aged 40, suffered a fracture of the lower end of the radius of the right arm, in consequence of a fall. She became an out-patient at the Middlesex Hospital, where a bandage was applied; but by the carelessness of the patient this got out of order, and the bone healed crookedly in consequence. It was then again fractured by a surgeon, and put straight; but the cure was now protracted over ten months; and when the bone was at last healed, the arm remained painful and entirely useless. She became some time afterwards an out-patient at the Samaritan Free Hospital, and was sent to me by

Dr. Henry G. Wright. Faradisation of the median and ulnar nerves was twice performed, when the pain was entirely gone, and the arm could be used as before.

CASE 28.—A gentleman, aged 46, when on a shooting excursion, in October 1867, accidentally shot the thumb of his right hand off at the metacarpal joint. The wound took nearly six weeks to heal, and it was then found that the hand was completely paralysed. Strychnia and stimulating embrocations were used, but without any effect; and the hand was totally useless when the patient consulted me in April 1868. One application of the continuous current restored the mobility of the hand; but as it was still weaker than the left, the current was applied three times more, after which the hand was as useful as it could be *minus* a thumb.

CASE 29.—A young lady, aged 15, of scrofulous habits, suffered from an abscess on the right side of the neck, which had to be opened, and was rather slow to heal. When the wound was quite closed, it was found that there was complete loss of power in the left trapezius and other muscles which execute the lateral movement of the head, so that the patient was unable to turn the head to the left side, while she could turn it to the right. I was consulted some time afterwards (July 1869), and applied the continuous current intermittently to the suffering muscles. After the current had acted for about ten seconds, I desired the patient to make an effort to move her head to the left, when it was found that she could do it, although not easily. A few more applications completely restored the power to the muscles which had been paralysed.

7. *Peripheral Paralysis from Injury to the Nerves* (*Traumatic Paralysis*).—The pathology of these affections has already been discussed. They occur chiefly in consequence of accidents, gunshot wounds, or from pressure by tumours or effusions. The degree of functional disturbance is directly proportional to the extent of the lesion. Where a nerve has been actually destroyed, the properties of the muscles animated by it are totally lost; but where the continuity of the nervous fibres has only been more or less

damaged, the muscles are weakened, and their sensibility and excitability to the faradic stimulus diminished.

On the whole, it cannot be said that the results of treatment in cases of this kind are very brilliant. We have seen that the conductivity of the paralysed nerves does not reappear before at least two or three months have elapsed after the occurrence of the injury, and that four, six, or even more months are necessary for recovery. Whether an electric treatment has much influence in expediting this regeneration has not yet been ascertained. Of course, where faradisation or galvanisation are employed shortly before the conductivity may be expected to become re-established, the results will apparently be excellent; but where the treatment was commenced in the beginning, the effect has generally not been so satisfactory. Nevertheless, electricity is the most rational remedy we possess for peripheral palsy. Erb believes that the constant current, by its catalytic effects, assists in removing the effusions of blood and serum which have taken place at the seat of the injury; and is supported in this statement by M. Chéron.[1] Dr. Mitchell,[2] of Philadelphia, who has probably the largest experience in cases of peripheral palsy from gunshot wounds, has come to the conclusion that it is best in all cases to apply electricity at the earliest date at which the healing of the wound allows of its use, and combines with them daily shampooing and alternate hot and cold douches. He believes that electricity sustains nutritive action, and that a larger supply of blood is given to the inert tissues than would enter them if they were not incessantly stimulated and subjected to those alterations of temperature, rest, and motion which belong to the normal state of limbs. When once the nerve is repaired, it finds the muscles in a far better condition to profit by it than could otherwise

[1] Journal des Connaissances médico-chirurgicales, 1871, pp. 19–21.

[2] Injuries of Nerves and their Consequences. Philadelphia, 1872, p. 245.

have been the case. He recommends to apply electricity on alternate days, from fifteen to thirty minutes each time; and as far as the form of electricity is concerned, to prefer the one which acts best on the muscles. In peripheral, therefore, as well as in infantile paralysis, the constant current will generally be the best; it is, however, according to Dr. Mitchell, very largely a question of time and patience, for muscles which seem only capable of response to galvanism, will more slowly but surely amend under the use of faradism. It is advisable to lessen the power as the muscles regain their excitability. If the muscle fails to reply either to galvanism or faradism after three or four sittings, the case is a bad one; where a response to galvanism is obtained, we may be allowed to hope for a cure, but there is not always a certainty of it. It also happens that in certain muscles which for a long time fail to respond at all to electricity, the persistent use of it nevertheless in time restores functional health. An increase in the bulk and warmth of the limb often precedes the return of electric excitability, and may lead us to a hopeful continuance of the treatment. In many cases it is advisable to interrupt the electric treatment for a month, after it has been continued for two or three months. If neuralgia should come on during the treatment, it is also better to discontinue it for a time, although the occurrence of neuralgia is no unfavourable sign.

Case 30.—A porter, aged 32, suffered compound fracture of the right arm and other injuries from being run over by a van, in December 1860. After three months the fracture was healed, but the arm remained useless. He came to me in May 1861, when I found complete anæsthesia, paralysis, atrophy, and loss of faradic contractility of the muscles, from the acromion downwards. I recommended him to do nothing for three months, and then to present himself again. This he did in the October following, when he appeared to be much in the same condition as

when I first saw him. I then commenced the faradic treatment, and after four months he had to a great extent recovered the use of the arm, although it was still a good deal weaker than previous to the accident.

CASE 31.—An unmarried lady, aged 30, of delicate constitution and sedentary habits, was sent to me by Dr. Thorowgood in June 1868. She had had a railway accident, near Basle, in Switzerland, in September 1867, when the carriage in which she was seated fell down a steep bank and was upset. She was stunned for a time, but soon recovered herself. Her right collar-bone, however, was broken, and the skin and subjacent parts on the lower half of the right fore-arm were severely lacerated. For a fortnight after the accident she felt 'pins and needles' in her arms and legs, but had not done so lately. The fracture of the collar-bone healed in two months, and the injury to the soft parts of the fore-arm likewise. Three deep scars are seen on the front of the latter. There were all the symptoms of certain branches of the brachial plexus having considerably suffered. Cutaneous sensibility in the lower part of the fore-arm, the hand, and the fingers, was diminished; the third finger being the worst in this respect. Concerning the sense of touch, it was found that the two points of the æsthesiometer were felt at the proper distance in the first, second, and little finger, but not in the third, where only one point was felt. Electro-cutaneous sensibility, both from faradisation and galvanisation, was likewise impaired, more especially in the third finger. The interossei and lumbrical muscles of the right hand were weak and wasted; the intra-metacarpal spaces being hollow and the bones protruding. Farado-muscular contractility was much diminished, but nowhere completely lost; galvano-muscular contractility was somewhat increased. The patient experienced much difficulty in carving, dressing, writing, and buttoning her sleeves and gloves; but she could do all these things with an effort. She was able to bend the first phalanges, but not the second and third. There was no difference of temperature in the two hands. The lower portion of the fore-arm was emaciated, there being a difference of seven-eighths of an inch between the two arms; for, while the left arm measured fully seven inches, the right measured only six and one-eighth. The general health of the patient was satisfactory. I applied the positive pole of twenty cells to the cicatrices in order to promote, if possible, the regeneration of the nervous fibres;

and also acted intermittently on the suffering muscles. After four such applications the patient felt a good deal stronger in the arm and wrist; she could hold things better, did not feel so stiff in writing, and her hand and arm did not ache after writing as they used to do. She also found carving and dressing easier, and had succeeded in turning a key in a lock, which she could not do before. After a few more applications, the third finger, which had formerly appeared as a 'dead log,' recovered its sensibility, and she felt the prick of a pin and the two points of the compasses quite distinctly. The metacarpal spaces became more filled up, and when she left town for change of air, a month after the commencement of the treatment, the arm and hand were much more useful than before, although not quite recovered.

Cases of paralysis from continued pressure, especially from the head resting on the arm, which occurs not unfrequently during intoxication by alcohol, or in patients who are under the influence of chloroform, are generally curable by faradisation or galvanisation.

CASE 32.—A lady, aged 23, had her first confinement in November 1864, during which she was for some time under the influence of chloroform. While in this condition her head rested heavily on the left arm, and pressed so much on the brachial plexus that a number of muscles, animated by the latter, became completely paralysed, there being also anæsthesia of the left arm. She was sent to me, in January 1865, by Sir James Paget. The affection was most severe in the muscles of the fore-arm, the patient being quite unable to lift the wrist, which was much swollen and had to be bound up with a splint. As she also complained of great weakness in the other limbs and the back, I combined a cord-current of fifty cells with faradisation of the left shoulder and arm. After six weeks of this treatment, the patient had entirely recovered the use of the left arm, and felt much stronger generally.

CASE 33.—Count Z., aged 63, had, about twenty years ago, suffered from a rupture of the capsular ligament of the hip-joint in consequence of an accident, and had never quite recovered from the effects of it. He complained of great numbness and

stiffness in the right leg, the muscles of which were not nearly so well nourished as those of the left, so that he had much difficulty in walking. The affection was evidently due to pressure from effusion and extravasation of blood. Sir James Clark, whom he consulted in June 1857, believed that faradisation would be the best means to restore him, and sent him to me. The patient was considerably improved by a short treatment, but as he left town soon afterwards to return to Russia, the cure was not complete.

The following case has been treated successfully by Dr. Walter Smith [1] :—

An Irish farmer, while driving in his gig on January 5, 1869, was fired at in consequence of an agrarian dispute in which he had become involved. He was struck in the left arm and the left side of the chest, and, as the gun was discharged close to him, he would probably have been mortally wounded were it not for the protection which three coats afforded. A considerable amount of blood was lost at the time. The marks of twelve cicatrices of different sizes were visible on the inner and under surface of the left arm, above the elbow-joint, some of them very small, being caused by grains of shot, others larger and more irregular, caused by slugs. One grain of shot remained imbedded under the skin, close to the median basilic vein, having travelled from behind forwards, for there was no trace of wound anteriorly. Common sensibility was impaired along the little finger and ulnar side of ring finger, and he could not distinguish between a wet and a dry object, nor take cognisance of the nature of any substance he touched. He was acutely sensitive to tickling and to the sudden impression of a point, which produced a feeling like a foot awaking out of 'sleep.'

The left fore-arm measured 25·5 centim. (10 in.), right 26·5, (10·5 in.). A heated body was not felt so plainly along the track of the left ulnar as along the right ulnar nerve. The muscles of the left wrist were weakened, the ball of the thumb flattened and flabby, and the fork of the first finger atrophied—and, indeed, all the interossei enfeebled. Faradisation was resorted to, and the grain of shot, which lay under the skin close to, and probably touching, the internal cutaneous nerve, was removed.

[1] Dublin Quarterly Journal of Medical Science, August 1870.

The extraction of the shot gave him great relief, and he was now able to rest his arm on the table with comfort, a position which previously caused pain. The extensor muscles and interossei responded freely and perfectly to electric stimulation, an omen of speedy recovery; but a moderate current, which was acutely felt on the sound arm, was not perceived on the left arm at its lower half. In a few days, under the use of faradisation, he felt as 'if the life had come back into the arm;' the feeling of cold and the numbness along the ulna disappeared, and in a short time he was perfectly well.

Paralysis of the brachial nerves may be caused by the use of crutches; and is only peculiar by its cause, as the cases otherwise resemble ordinary traumatic paralysis. In crutch-paralysis the radial nerve is chiefly affected, being compressed at a point where it winds round the humerus, between the bone and the transverse part of the crutch. Dr. Krafft-Ebing[1] has recorded the following case of this kind:—

A French soldier, aged 22, was shot in the leg on December 18, 1870. In the beginning of March 1871 he commenced walking with badly-stuffed crutches. Within the first half-hour there was numbness in the whole left arm, 'pins and needles,' heaviness, motor paralysis of all the muscles, excepting the deltoid. He did not pursue his walking, and used an embrocation to the paralysed muscles, which became wasted. In April the paralysed arm was one inch less than the other, and the paralysed fore-arm one and a half inch less. Skin cyanotic, temperature diminished; 'pins and needles' in the limb. Only the posterior surface of the arm had preserved its sensibility; otherwise this was entirely gone, and no reflex movements could be produced. The deltoid muscle was normal and responded well, also the lumbricales and interossei; all other muscles were paralysed. Galvanic and faradic excitability was normal. Galvanisation and faradisation of the nerves and muscles was daily used for five minutes at a time. After ten such applications the median, and after thirteen the ulnar, nerve recovered; the radial nerve required thirty-four applications. After this the patient was quite well. Dr. Ebing has seen four similar cases, which all recovered under

[1] Deutsches Archiv etc. Band IX., 1872, p. 125.

the same treatment and recommends the use of crutches well-stuffed with horsehair and india-rubber, and also a support for the hand, which diminishes the pressure on the axilla, and allows the occasional use of the crutch as a stick.

CASE 34.—*Neuritis of the Brachial Plexus.*

D. D., a girl, aged 16, was admitted into the Infirmary for Epilepsy and Paralysis, under my care, on July 18, 1870, with paralysis of the right upper extremity. She had been in good health before the present affection came on. In April last she suddenly began to complain of pain and numbness in the right hand and arm; the next few days she experienced a loss of power in those parts; the fingers appeared white and the skin peeled off. The weakness of the muscles gradually became more marked, and in about ten days from the commencement of the affection she had completely lost the use of the whole arm and shoulder. She now attended as an out-patient at the West London Hospital, where she was treated with bromide and iodide of potassium, nux vomica, belladonna, and later on with the syrup of iodide of iron and cod-liver oil. For the relief of the pain, liniments of aconite and chloroform, subcutaneous injections of morphine, chloral, and a blister to the neck, were used, and faradisation was resorted to daily for a month, in order to restore the lost power; yet (to use the words of Dr. Wiltshire, under whose care she was, and who has given me these particulars), 'she only got worse from first to last;' and she was then sent to the Infirmary, where she was admitted under my care.

On examining the patient, I found that there was complete paralysis of motion and sensation of the whole upper extremity, no voluntary movements of the hand, arm, and shoulder being possible, and no touch, pricking, or pinching being in the least degree perceived by the patient. Faradisation of the skin, and of the nerves and muscles of the shoulder and arm, likewise remained ineffectual; but when I applied a continuous current of Daniell's battery to the arm, the patient exclaimed that she felt a sensation of tingling in the arm and fingers; and the muscles responded to the current by sluggish, yet plainly perceptible, contractions. Any lesser galvanic power than sixty pairs of the battery did not produce any effect, while under ordinary circumstances a current of twenty cells causes not only

decided sensations of heat and tingling, but also muscular motion.

In this case I gave no medicine whatever. The patient had been already treated medicinally by an able physician, who had used all the remedies upon which we look with most confidence in the management of such affections, yet the result had been absolutely *nil*. On the other hand, the general health of the patient was so good that no medicines were required on account of that. All that was done was, therefore, a systematic daily application of the continuous current to the suffering limb, for about five minutes each time. The result of this treatment was most satisfactory. After four applications, sensation returned in the paralysed limb, so that the patient was again able to perceive touch, pricking, pinching, &c., just as well as before the commencement of the affection. The paralysis of motion proved more stubborn; but after seven applications the girl was able to move her fingers. The treatment was continued for another fortnight, at the end of which the patient could not only move all her fingers, but also flex and extend the wrist. I then discharged her, as I was anxious to see whether she would continue to improve on the treatment being suspended, or whether she would remain in the same condition. It might have been said that a process of natural cure had set in; that the progress the patient had made was simultaneous with, but not owing to, the galvanic treatment; in fact, that the good results hitherto obtained were not *propter hoc*, but *post hoc*.

Six weeks after her discharge the patient presented herself again at the Infirmary, and it was then found that she was absolutely in the same condition as when she had left it. She had not gone back in the interval, but she had made no progress whatever, the arm and shoulder being just as useless as before. The supposition of a natural process of cure could, therefore, not be entertained; and as the patient and her parents were very anxious that the treatment should be resumed, she was readmitted on September 27. The use of the continuous current was now recommenced, with the result that in a very few days a further decided improvement took place; the patient soon became able to move the hand, arm, and shoulder in all directions, and to grasp things with some force. She was, however, not discharged until the power of the right arm was in all respects quite equal to what it had been previous to the commencement of the affection. The recovery of power went on steadily from

the periphery to the centre, the fingers being the first and the shoulder-blade the last to regain it. The patient was sent home on November 28, perfectly recovered.

What was the actual nature and seat of the paralysing lesion in this patient? Cerebral paralysis is extremely rare in persons of the age of this girl; it generally comes on suddenly, not gradually, as in the present case, where the invasion of the complaint was protracted over ten days. Again, cerebral paralysis almost always affects one side of the body, the face and leg as well as the arm; while in this case the cerebral nerves and the lower extremity did not at all suffer. Cerebral paralysis is only very rarely accompanied with complete anæsthesia, for most patients suffering from it, although they may be completely deprived of the power of motion, retain sensation in a more or less considerable degree. All these circumstances, taken collectively, speak strongly against the cerebral origin of the palsy; but one more remains to be mentioned, which puts the matter completely at rest, and which is, that in cerebral paralysis, whatever may be the extent of the loss of power, the nerves and muscles always retain their excitability to faradisation. There is no exception to this rule, and the absence of faradic excitability in the present case was quite sufficient to make us reject the idea that in this patient the brain was the seat of the paralysing lesion.

Was it, then, a case of spinal paralysis? To this question we may also return a negative answer; for if there had been disease of the upper portion of the spinal cord or its meninges sufficiently severe to cause total paralysis and anæsthesia of the whole upper extremity, the intercostal muscles, the diaphragm, and the lower extremity, would have participated in the affection. Another circumstance, which speaks against the supposition of spinal paralysis, is that in the earlier stages of such an affection the muscles do not lose their excitability to

faradisation. Nor could the paralysis in this instance have been due to lead-poisoning. There was no evidence to show that this girl had ever been exposed to the influence of lead; there was no blue line on the gums; she had never suffered from colics or obstinate constipation; and what is even more important, the general aspect of the palsy in her case was entirely different from that which occurs under the influence of lead. In lead-palsy generally both arms are affected, and it is almost exclusively the extensor muscles of the hand and forearm which suffer, while the flexors either escape completely or only become weakened to a moderate degree. Whenever lead-palsy is severe, there is great deformity of the fore-arm, the back of which is hollowed by atrophy of the extensors, while the wrist drops. In the present case, however, although the paralysis was complete, the arm retained its shape and plumpness. There was not one particular set of muscles which suffered more than another, but all the muscles of the whole extremity were indiscriminately affected.

Cases of hysterical paralysis without structural lesions whatever are not rare, but the present case was not one of them. The girl had never shown any symptoms of hysteria. Moreover, the invasion of hysterical palsy is quite different from that which was observed in this case, as it almost always comes on quite suddenly, after a violent mental emotion; while in this case the progress of the loss of power was protracted over ten days. Hysterical paralysis almost always affects either the vocal cords or the local extremities, giving rise to aphonia and paraplegia. This girl, however, had never lost her voice nor been unable to walk. Moreover, in hysterical paralysis the motor nerves and muscles retain their excitability to faradisation for years after the commencement of the affection, while in this case it was lost within a few weeks of the beginning of it.

The question might now be asked, whether the case was one of nervous or muscular disease. This admits of a ready answer. The fact that not only motive power, but also sensation, was completely annihilated, speaks sufficiently for some part of the nervous system being in fault; moreover, there is no muscular affection which takes away motive power without altering at the same time the bulk of the extremity. In the present case, however, the bulk of the suffering limb was exactly the same as that of the healthy limb.

The last question we have to consider, as far as diagnosis is concerned, is whether the girl was malingering. It is well known that girls, especially at the age of this patient, are given to deceitful practices, in order to excite wonder and interest, and that they will continue the deceit for months and even years (e.g. the Welsh fasting-girl). But this question is likewise disposed of by the result of the electrical examination. Malingerers may have sufficient control over themselves to bear without flinching severe pain, as produced by pricking, pinching or burning; but it would be absolutely impossible for them to resist the influence of an induced current of high tension in making their muscles contract. This influence is irresistible where the nerves and muscles are in a healthy condition, and the question of shamming may therefore be dismissed.

After excluding all the various affections which we have considered, we are led to the result that the disease must have been due to a pathological lesion of the anterior branches of the four lower cervical nerves, which form the brachial or axillary plexus. This plexus imparts motive and sentient power to the whole upper extremity; it animates the rhomboid muscles, the serratus anticus, the supra- and infra-spinatus, the subscapularis, the anterior portion of the latissimus dorsi, and all the flexors and extensors,

pronators and supinators of the arm and hand. Not one of these muscles had escaped the paralysing influence, while muscles in their immediate neighbourhood, which are animated by different sets of nerves, had remained in perfect condition. Thus, for instance, the trapezius and the sterno-cleido-mastoid muscles were in no way impaired, for the motion of the head forwards, backwards, and laterally had always been quite easy; nor did the cervical plexus, formed of the anterior divisions of the four upper cervical nerves, suffer; for there had never been the least interference with respiration, showing that the phrenic nerve, which arises from this plexus and animates the diaphragm, had escaped the paralysing influence. Moreover, the skin of the back of the head, the neck, and the ear, had never lost its sensibility—a circumstance which excluded an affection of the sentient branches given off by the cervical plexus, which animates the skin of the parts just mentioned. On the other hand, the skin of the arm, from the acromion downwards, was totally anæsthetic, while the sensation on the shoulder-blade was blunt, although not quite gone. That the skin of the shoulder-blade should have preserved a certain amount of sensibility is explained by the circumstance that it receives sensitive influence, not only from branches of the brachial, but also from such of the cervical plexus which, as we have already seen, did not participate in the disease.

It would be difficult to determine in which point of its transit the brachial plexus was affected. When I examined the patient, there was no thickening or tenderness perceptible anywhere in its superficial course which could have led me to fix upon the precise seat of the pathological lesion; but as not one of the motor or sentient branches of the whole plexus had escaped the paralysing influence, the seat of the disease must have been at some point of the plexus before its entrance into the axilla.

It now remains to determine the nature of the disease which had affected the brachial plexus. We may at once exclude injury to, and tumour pressing upon, the plexus, of neither of which was there any history or evidence. Inflammations affecting the plexus may be of syphilitic, gouty, or rheumatic character; and as there were no symptoms of gout or syphilis in the patient, we are led to the conclusion that the case was one of *rheumatic neuritis of the brachial plexus.*

Whether such a disease, with its sequelæ, may be influenced by any purely medicinal treatment, is extremely doubtful. The patient had, before she came under my care, been treated for more than two months by a very able physician with those remedies which we look upon with most confidence in the management of such affections; yet there was no improvement whatever. The disease, however, yielded readily to a judicious application of the constant current. Sensation, after having been completely lost for about four months, returned within a few days from the commencement of this treatment. Motion was recovered more slowly but steadily, and in exact proportion as the galvanic treatment was continued. The fact that no improvement whatever took place during the six weeks which the patient spent at home between the two periods of her stay in the hospital, while she immediately improved each time the galvanic treatment was commenced, is sufficient to show that the recovery was not due to the unaided efforts of nature, but was really owing to the influence of the particular plan of treatment which was adopted.

The mode of action of the constant current in this case was of a complex nature. In the first instance, it prevented granular disintegration and atrophy of the paralysed muscles, by making them contract. The induced current could not have done this, and it is therefore a great boon that we

possess in the constant current an agent which will, if properly applied, cause muscular contractions under any circumstances, as long as the muscles have not utterly lost their normal structure.

This was, however, not the only beneficial effect which galvanisation produced in the present instance. We have seen that by its means sensation was within a few days restored to its normal condition. It is therefore evident that the current re-established the conductivity of the sentient fibres of the brachial plexus, which was completely lost previous to its application. The current did the same thing, although more slowly, with the motor branches of the plexus, since the mere causation of muscular contractions, although useful for preventing atrophy, would never have restored that nervous influence to the muscles which enables them to respond to the orders of volition. It is therefore necessary to assume that the current removed the rheumatic effusion which pressed upon the plexus, and thereby rendered it unable to fulfil its function. By effecting dilatation of the blood-vessels of the suffering parts, the current obviously enabled them to take up and remove into the general circulation pathological products which, by their presence, impeded the conveyance of the nervous influence to the distal parts of the nervous district.

Whether there was in the present case actual destruction of nervous matter, such as occurs through mechanical injury or tumours, and whether galvanisation promoted or accelerated its regeneration, it would be difficult to determine. But, looking at the rapidity with which sensation was restored, it seems more rational to assume that the inflammation, although sufficiently severe to cause entire loss of function, had not proceeded to absolute destruction of the nervous matter, but had caused effectual compression of the same, which was removed by the catalytic effects of the current

setting free the nervous force which had been rendered inactive through interrupted conduction.

8. *Infantile paralysis* is either owing to cerebral hæmorrhage or to disease of the antero-lateral columns of the cord. Unfortunately, most cases of this kind are only submitted to a galvanic treatment when muscular atrophy has already become thoroughly established. On examining the paralysed limbs, we generally find that farado-muscular contractility is much diminished, or even entirely lost, in all the paralysed muscles; the muscles and bones are wasted; the paralysed limb is shorter and thinner than the healthy one; and the temperature in the former is considerably lower than in the latter. The sensibility of the skin, the muscles, and the nerve-trunks is, however, not impaired. Benedict has seen a few cases where, in the commencement of the affection, the motor excitability to the constant current was much increased.

Infantile paralysis resists all purely medicinal treatment, and only improves under the long-continued use of faradisation and galvanisation. Dr. Russell Reynolds,[1] who has written an able paper on this subject, recommends the alternate use of these two agents, and my experience coincides with that of Dr. Reynolds. I generally advise a month's galvanisation, then a month's rest, and a month's faradisation, and so on. Gymnastic exercises, shampooing, frictions with stimulating liniments, a meat diet, and the internal administration of phosphorus, may be combined with electricity.

9. *Labio-glosso-pharyngeal paralysis* (Duchenne), or *progressive bulbar paralysis* (Leyden), is owing to progressive atrophy of the cells of the nuclei of the nerves in the rhomboid fossa, more especially of the nucleus of the hypo-

[1] Lancet, vol. i. 1868.

glossus at the calamus scriptorius, and less so of the nucleus of the pneumogastric. Benedict is the only observer of repute who has seen curative effects of galvanisation in this disease; and he ascribes the fact of other electro-therapeutists not having been equally successful, to the circumstance that he was consulted at an early stage of the complaint, when the structural alterations which ultimately destroy life had not yet been allowed to become fully developed. He recommends galvanisation of the sympathetic and of the mastoid processes continuatively, and of the muscles of deglutition intermittently.

10. *Paralysis after acute diseases* is, on the whole, rare. Typhoid fever seems to give rise more frequently to it than small-pox, scarlet-fever, pneumonia, erysipelas, dysentery, cholera, and puerperal fever. During the late Franco-Prussian war, a not inconsiderable number of cases of post-typhoid paralysis occurred; and Dr. Nothnagel[1] has described fourteen cases of this affection, which came under his observation in the electro-therapeutical department of the military hospitals of Breslau and Berlin. This kind of paralysis affects either certain sets of muscles animated by one nerve, such as the ulnar or peroneal, or a whole limb, or two limbs which are not symmetrical. Hemiplegia is rare, but paraplegia somewhat more frequent. Zenker has drawn attention to a peculiar degeneration of the muscular tissue which occurs in typhoid fever, and some physicians are inclined to think that post-typhoid paralysis is owing to that degeneration; but if we consider the peculiar localisation of the palsy in certain nerve-districts, and also the circumstance that neuralgia and anæsthesia are generally combined with it, the nervous origin of this form of paralysis cannot be questioned. Post-typhoid hemiplegia and paraplegia are probably owing to cerebral and

[1] Deutsches Archiv etc. vol. ix. p. 480.

spinal hæmorrhage, while the local forms of the complaint may be traced to neuritis. The best treatment for post-typhoid paralysis appears to be that by galvanisation, faradisation, and thermal springs. Where there is much wasting of the affected limb, the constant current is the only remedy which does any good, and great perseverance with it is necessary for ensuring a satisfactory result.

11. *Diphtheritic paralysis* is well known clinically, but not so well pathologically. There are probably two different kinds of it, viz. one which is owing to poisoning of the blood, and consequent alterations in the nutrition and molecular condition of the nervous system—there may be effusions in the neurilemma, but these are rapidly absorbed; while in another class of cases there are coarser anatomical alterations in the suffering nerves and their neighbourhood. Thus Buhl [1] has found capillary apoplexy of the brain, thickening and softening of the anterior and posterior roots of the spinal nerves, from diphtheritic infiltration of the neurilemma and the interstitial connective tissue. Again, Oertel [2] discovered large granular masses imbedded in the mucous membrane of the pharynx, larynx, trachea and lungs, in the heart, stomach, kidneys, interstitial connective tissue of the muscles, the meninges and vessels of the brain and spinal cord, the anterior horns of the grey matter of the cord, and the neurilemma. Cases of the latter kind generally end fatally, or if the patients recover, the affection is most obstinate; muscular atrophy supervenes, and galvano-muscular and farado-muscular excitability undergo considerable alterations.

Diphtheritic paralysis generally commences in the second or third week after the diphtheritic process has affected the throat, conjunctiva, vagina, or other organs. It is often preceded by vomiting and considerable retardation of the pulse;

[1] Zeitschrift für Biologie, vol. iii. p. 341.
[2] Deutsches Archiv etc. vol. viii. p. 242.

and is characterised by the peculiar manner in which the motor tracts are successively affected. The soft palate suffers first; speech becomes nasal and indistinct, deglutition is impaired, but the muscles of the tongue and larynx are very rarely affected. The motor nerves of the eye then begin to suffer; there is mydriasis and disturbed accommodation; the lower and upper extremities, the muscles of the trunk, and the respiratory muscles, may become affected in the order in which they have just been mentioned. Anæsthesia is sometimes present, and occasionally ataxy and impotency supervene. The best treatment of diphtheritic paralysis is by galvanisation and faradisation alternately. This may be combined with change of air, tonics, and baths.

Dr. Greenhow[1] has cured the following case by faradisation:—

A woman, aged 26, had diphtheria in October 1871, and been confined to her bed for about a fortnight. A week after the sore-throat subsided, and when she had already left her bed, the liquids she drank began to be returned through her nostrils, and her voice became so thick that she was scarcely intelligible in speaking, although she was able to swallow solids without difficulty. About the same time her vision became impaired for near objects. When she first began to move about, she felt numbness in the toes of the left foot, which gradually spread up the leg as high as the hip. Two months afterwards she began to experience a similar feeling in the right foot, which spread as high as the knee, and a deadness in the fingers, which rendered her incapable of buttoning or fastening her dress or of handling any object properly. This spread up as high as the elbows. She sometimes passed her urine involuntarily and often vomited her food; she also occasionally suffered from vertigo, and had a feeling of tightness round the chest and the abdomen. Loss of power in the lower limbs now came on, which also commenced in the left leg; she was uncertain in her walk, and found her limbs give way under her; she was breathless on attempting to go upstairs.

On admission, the muscles of the extremities were flabby and wasted; she could move the legs freely in bed, but stood in a tot-

[1] Transactions of the Clinical Society of London, 1871, p. 148.

tering manner, and even when supported could only walk two or three steps with much difficulty, and dragged her left foot on the ground. She was unable to write or work, and handled things clumsily. Firm pressure on the left sciatic notch caused extreme pain, which extended down the thigh and into the calf of the leg. The sense of temperature, of tactile sensibility and tickling, was much impaired. Farado-muscular excitability was diminished in the lower extremities and the hands. The throat was healthy, the pulse feeble but regular, the hearing somewhat dull, the urine normal.

Only a placebo was given, and faradisation of the nerves and muscles of the extremities resorted to. In twelve days she was able to dress herself, and could do crochet-work for a short time. A few days later she lost the tenderness on pressure over the left sciatic nerve, and could distinctly feel the prick of a pin in both calves. Three weeks after admission she could walk a few steps without assistance, could stand for a few moments on the right foot alone, but not on the left. The muscles became plumper and firmer, and two months after admission she left the hospital perfectly well.

Dr. Krafft-Ebing [1] has described a case in which he electrically diagnosed the peripheral character of the paralysis, as arising from compression of the nerve. A man, aged 30, had diphtheria. At the end of the first week, deglutition was difficult, the voice nasal; there was strabismus and difficult accommodation for near objects; both sides of the face and all extremities, except the fore-arms, paralysed. This occurred within four days. There was cutaneous and muscular anæsthesia of the paralysed parts. Bladder and rectum unaffected; no pain. The mobility of the right big toe returned a week afterwards, and the velum likewise recovered. Cutaneous and muscular sensibility reappeared in the right side two days later. Nevertheless, the paralysed muscles wasted rapidly, and only increased again in bulk three months afterwards. Ten months later the patient could stand; in eleven months he could stagger through the room with the aid of a stick; in the fifteenth month cutaneous and muscular sensibility returned in the left side of the body, and the sensibility and muscular force gradually improved in the right leg.

After seventeen months the patient underwent a galvanic treatment. At that time there was a high degree of wasting in the

[1] Deutsches Archiv etc. vol. ix. 1872, p. 123.

muscles animated by the crural, obturatorius and glutæi nerves. Cutaneous sensibility was everywhere normal. Adduction and abduction of the thigh, inward and outward rotation in the hip-joint, almost impossible; he could not rise from a chair without supporting himself with the hands, and could not hold the stretched leg up; active and passive movements caused clonic spasms of the paralysed muscles. Walking and standing was only possible with a stick, and even so very fatiguing; going upstairs was almost impossible. The right leg was weak, but did not show trophic disturbances. In the right side the electric reaction was normal, in the left farado-muscular contractility gone, the galvano-muscular excitability preserved, and the anode acted more powerfully than the cathode.

The cord-nerve and plexus-nerve-current was used, together with faradisation of the paralysed muscles, for a month. After a week, the tensor fasciæ recovered its faradic contractility; in three weeks the adductors and glutæi muscles recovered their volitional power. There was muscular hyperæsthesia at the same time. The rectus of the thigh began to recover in the fifth week. Thirteen months afterwards the patient was quite well.

12. *Palsies of the nerves and muscles of the eye.*—If the *third* nerve or motor oculi is paralysed, the upper eyelid droops and cannot be raised through loss of power in the levator palpebræ superioris muscle (ptosis); the pupil is dilated and the eye cannot be moved in any direction except outwards, as the rectus externus, being animated by the sixth nerve, retains its function. This muscle is, however, after a time, generally affected by secondary contraction, which causes divergent squint and double vision.

Local palsy of the *fourth nerve* is of rare occurrence. Professor A. von Graefe[1] states that in this affection the pupil is turned a little upwards and inwards; when looking upwards, vision is not disturbed, but in looking at an object placed horizontally before the eye, the patient sees it double; and therefore, in order to avoid this, the head is generally turned towards the opposite side.

[1] Archiv für Ophthalmologie, vol. i. p. 1.

If the *sixth nerve* is paralysed, the patient squints inwards, and has double vision in certain directions; sometimes the inward deviation of the eye is so considerable, that the cornea may be entirely concealed at the inner angle of the orbit.

These palsies may be caused by cerebral affections; but are more frequently owing to rheumatic or syphilitic effusions, or to over-exertion of the eyes, or to pressure by tumours and exostoses. The patients are generally treated with iodide of potassium and counter-irritation of the skin in the neighbourhood of the eye; and some recover by that treatment. Operative interference has often been attempted, but generally left the patient in a worse condition than he was before the operation. Where the usual means do not improve the condition of the paralysed muscles, both faradisation and galvanisation may be employed. M. Meyer,[1] Mr. Soelberg Wells,[2] and myself, have seen very favourable results of the former; while Benedict [3] expresses himself strongly in favour of the latter. When using faradisation, I generally place the positive pole below the ear, and a small moistened sponge connected with the negative pole to the skin of the closed eyelid, as near as possible to the paralysed muscle, sending the current through for two or three minutes. For galvanisation, Benedict recommends to apply the positive pole to the forehead, and in ptosis, to draw the negative pole over the lid; in paralysis of the rectus externus, to put the negative pole to the cheekbone; and in paralysis of the rectus internus, to draw it over the skin of the side of the nose. He is quite corrrect in stating that a good result is often obtained instantaneously, and that the application should be short and feeble; but he is wrong in denying the

[1] Deutsche Klinik, 1856, No. 38.
[2] A Treatise on the Diseases of the Eye, London, 1869, p. 568.
[3] Archiv für Ophthalmologie, vol. x. p. 1.

beneficial influence of faradisation in these cases. Only a short time ago I had a patient under my care who suffered from paralysis of the rectus internus muscle, and in whom the continuous current was applied for a fortnight without any benefit. I then resorted to faradisation, with the effect that the patient felt a great deal better after the first application, and rapidly recovered under a continuance of the faradic treatment. The rule should therefore be to apply either one or the other form of electricity, and not to continue either for any length of time if no decided benefit be produced.

CASE 35.—A lady, aged 43, who had been in the habit of over-exerting her eyes, being very fond of painting in water-colours, was exposed to wet and cold in November 1861, and suddenly noticed that she saw everything double. A blister was applied behind the ear, and she was freely purged, after which she was put on a course of iodide of potassium. As she did not get better, she came to me in February 1862, when I found paralysis of the left rectus internus muscle, probably from rheumatic effusion. I used faradisation six times, after which the double vision existed only for objects at a great distance, but not for near things. The patient was then obliged to leave town, but returned in May of the same year, and had ten more applications, after which the muscle had quite recovered and the double vision disappeared.

CASE 36.—A lady, aged 40, was sent to me by Mr. White Cooper in October 1862. She had for some time suffered from mydriasis of the right eye, which considerably interfered with sight. She was otherwise in good health, and unable to account for this affection. I applied a gentle current for a short time, which caused the iris to contract visibly. She was only able to stay in town for a few days, so that the treatment could not receive a full trial; but she was considerably improved even by the short treatment she had followed.

CASE 37.—A gentleman, aged 49, had for ten months suffered from ptosis of the left eyelid, for which he had undergone a variety of treatment without benefit, when he consulted me in December 1864. There were many other symptoms, exciting the suspicion of cerebral disease. He had six applications of

the continuous current to the eye in a fortnight, during which he recovered the power over the eyelid, although there was no improvement in the other symptoms.

CASE 38.—A clerk, aged 34, was sent to me by Mr. Soelberg Wells in July 1871. He had suffered from various forms of secondary and tertiary syphilis, for which he had been treated with mercury and iodide of potassium. The principal symptoms at the present time were ptosis of the right eyelid and paralysis of the right rectus internus muscle, which produced double vision. I applied the constant current to the suffering muscles, with the result that immediately after the first application the patient could raise the eyelid somewhat, and the rectus internus recovered some of its tone. The patient had altogether thirteen applications of the constant current, during which he gradually recovered the power of the muscles; and at the end of this treatment his eye was perfectly well.

Where both eyelids are drooping, we have generally to do with an incurable affection of the corpora quadrigemina; yet even in such cases the continuous current may prove of benefit, but which, I fear, is generally only temporary.

Mr. Carter[1] has lately recommended to combine faradisation of the paralysed muscle with tenotomy of the contracted one, and appears to have been successful in carrying out this treatment. He proposes to apply the electrodes directly to the muscular substance, the eyelid being lifted and controlled by a retractor, and the current being directed to that portion of the conjunctiva which corresponds to the situation of the muscle. Such an application is much more painful than the one I have recommended, and it would therefore be better first to use the electricity externally, and only in case this should not answer, to apply it internally. The combination of tenotomy with faradisation, however, may answer in cases where the use of either of these remedies singly might fail.

[1] Lancet, December 1868.

13. *Paralysis of the portio dura.*—Most cases of facial palsy are due to the influence of damp and cold. A rheumatic effusion takes place into the cellular tissue of the face, by which the peripheral branches of the portio dura are compressed and their function more or less inhibited. In such cases the lower portion of the face is generally more affected than the upper one. Cases which occur in children or young persons, and where the quantity of lymph effused is not very great, may get well spontaneously; but in adults, or where a large effusion has taken place, the palsy only yields to appropriate treatment. Where all the muscles of the face are equally affected, the nerve is, as a rule, compressed by an effusion in the Fallopian canal. In slight cases of this kind the farado-muscular excitability is diminished, and in severe cases it is lost. Galvano-muscular excitability is sometimes increased and sometimes normal, but only in exceptional cases diminished or lost.

The treatment generally employed in these cases consists of blistering and the internal use of iodide of potassium or strychnia. Electricity is, however, much more rapidly successful, especially if the affection be of recent origin. Many cases may be cured by faradisation; but where this fails, and likewise in those cases where farado-muscular contractility is altogether lost, galvanisation is preferable. Faradism should be applied to all the paralysed muscles individually; while if the constant current be used, the anode is placed to the auriculo-maxillary fossa, and the cathode gently passed over the peripheral branches of the portio dura. Voltaic alternatives are useful. Where the external application does not produce much benefit, the negative pole may be applied to the mucous membrane of the cheek, and the positive externally, which sometimes does good, after all other modes of applying electricity have failed.

Cases of rheumatic paralysis of the portio dura generally

yield to treatment even if they have existed for a very long time. Professor Oré has related a case of eight and a half years' duration, which was cured by faradism, and Dr. Russell Reynolds succeeded by the same means in notably improvin one of fourteen years' standing.

Facial palsy is also observed as a symptom of cerebral *hemiplegia*, but it then generally appears only in a few muscles of the face, viz. the levator alæ nasi et oris, and the buccinator muscle. In such cases electro-muscular contractility is either normal or increased to both kinds of current. As this form of facial palsy has a central origin, faradisation is not to be recommended. The palsy frequently disappears spontaneously, but where it continues troublesome some months after the attack, galvanisation may be resorted to, and generally proves successful.

In *tumours* of the corpus striatum and crus cerebri, and in disease of the pons, facial palsy appears combined with paralysis of the third and other cerebral nerves. In such conditions no form of electricity can be of decided or permanent use, although the constant current cautiously applied may relieve certain symptoms of the affection.

Facial palsy ensuing in the course of *locomotor ataxy* is generally an unfavourable sign, as it shows that the disease is gradually advancing towards the medulla oblongata, and the roots and nuclei of the cerebral nerves. The constant current may, however, under these circumstances be employed with a fair chance of temporary benefit.

Where facial palsy is due to *injury*, the prognosis is not so favourable as in those cases which are owing to rheumatic effusions. The injury may be due to external violence, such as a blow, shot, cut, fracture of the petrous portion of the temporal bone, pressure by the application of forceps, &c.; or to some pathological process in the internal ear, as caries and necrosis of the petrous portion of the temporal bone, or syphilitic exostoses.

There is one form of paralysis of the portio dura which has only quite recently sprung into existence, and which for want of a better term I propose calling *aural surgeon's facial paralysis.* It is produced by the reprehensible practice of injecting a caustic solution of nitrate of silver (from forty to sixty grains in the ounce) into the external meatus, for the relief of deafness arising from aural catarrh. The deafness is not relieved, and another very troublesome and annoying affection—paralysis of the portio dura from injury in the Fallopian canal—added to the one previously existing. In these cases farado-muscular excitability is entirely lost, but galvano-muscular excitability is preserved. It is fortunate for these poor patients that the physicians' skill may remedy the harm done by the surgeon's recklessness. The constant current employed regularly for two or three months entirely cures aural surgeon's facial paralysis. We are pleased to find that Dr. Peter Allen[1] has condemned the practice just mentioned as unjustifiable, and we trust we may have seen the last of these cases, which are an opprobrium to our profession.

From many cases of facial palsy which have come under my observation, I select the following:—

Case 39.—*Paralysis of the Face.*

Mr. F., a barrister, aged 35, having been exposed to a draught of cold air at a railway station, became affected with paralysis of the left portio dura. The physiognomical expression had entirely vanished from that side of the face. The patient was not able to laugh, frown, whistle, or to shut his eye, which latter appeared staring and protruded. The angle of the mouth was depressed, and drawn towards the opposite side; that of the sound side being higher and drawn towards the ear. The cheek was flabby and loose; and eating and speaking were troublesome. The patient was sent to me by the late Dr. Todd, whom he had consulted six months after the commencement of the affection.

[1] Lectures on Aural Catarrh. London, 1871, p. 258.

Farado-muscular contractility was diminished. I faradised all the paralysed muscles individually, with the effect that the patient regained his normal physiognomical expression, after a fortnight's treatment.

CASE 40.—George W., a shoemaker, aged 44, came under my care at the Infirmary for Epilepsy and Paralysis, on April 25, 1866. He had for the last ten weeks suffered from paralysis of the portio dura, which he ascribed to having got wet through, and been exposed to a cold draught in a doorway. He was unable to close his eye, to laugh, or to whistle, and could not pronounce the letter 'f.' The right nostril was 'shut up,' and he had great difficulty in masticating his food at the right side. He also complained of headache, and occasional attacks of vertigo; but was otherwise in good health. Faradisation produced no contraction in the muscles of the face, while the continuous current caused contractions both on closing and opening the circuit. A continuous current of twenty cells was now applied regularly twice a week, and after six weeks of this treatment the patient was quite well.

An interesting case of facial palsy, which appears to have been cured by a lightning-stroke, is that of Samuel Leffers, of Carteret County, North Carolina, U.S., which is generally quoted as an instance of amaurosis or general paralysis cured by lightning, and which occurred in 1806. In the United States the most marvellous particulars were circulated of the case, and Professor Olmsted,[1] who has recorded it, states that henceforth it was generally believed that under certain circumstances lightning would suddenly change decrepit old age into blooming youth. It was indeed related of Leffers, a very old man, who had been so much paralysed that he was no longer able to walk or even stand, and whose features were frightfully distorted, that he had through a lightning-shock suddenly regained the full force of his youth and an exquisitely beautiful complexion and soft skin, and that he had retained this complete youth up to his ninetieth year. The facts of the case are, however, as follows:— Samuel Leffers was affected by what is now generally known as paralysis of the portio dura, and which in most cases is only a troublesome and annoying, but by no means dangerous, affection. At the time, however, when this occurred, medical diagnosis had

[1] American Journal of Arts and Sciences, vol. iii. p. 100, 1821.

not advanced so far as it is at present, and this affection was not distinguished from paralysis of the face due to hemiplegia, and was therefore considered as a certain sign of the break-up of the patient's constitution. That Samuel Leffers' complaint was in fact nothing more than paralysis of certain branches of the facial nerve is evident from the description of his symptoms, which were as follows:—On awakening one morning he felt an unpleasant numbness in the left side of the face; he could not shut the left eye, and his speech was impaired. These symptoms 'caused him to believe that he had been affected by a paralytic stroke.' Some time afterwards the disease improved in the other parts of the face, and centred in the eye, which he could not shut by day or night; it was consequently exposed to obnoxious influences, and the sight became much impaired; that is to say, the buccinator and other muscles recovered their tone, while the orbicularis palpebrarum still remained paralysed. He was in this state when one day, while walking in the hall of his house during a storm, he was struck by lightning. He fell down, and remained unconscious from fifteen to twenty minutes, when he recovered so far as to be able to distinguish objects around him, and to be conscious of his position. During the night he fully regained the use of his senses and limbs, and felt so well the following morning that he resolved to write an account of what had happened to him, to a friend. He then supposed that, as he had not been able to see well for some time, his note must necessarily be a short one: but he was astonished to find that he could write a long letter without experiencing any inconvenience, the last remains of the paralysis having entirely disappeared; nor did it return at a later period. He had thus been effectually cured from his previous complaint; but his hearing had become weak, and he always afterwards complained of a certain degree of deafness. From this description, it is quite evident that the orbicularis palpebrarum muscle, which had been paralysed, was beneficially affected by the stroke; but the case was neither one of amaurosis, nor one of general paralysis cured by lightning.

13. *Paralysis of the Vocal Cords: Aphonia and Dysphonia.*—The introduction of the laryngoscope into medical practice has greatly facilitated the diagnosis of diseases of the larynx; and the treatment of these affections is now

more easy, safe and successful than it could have been before. Where loss of voice is due to pressure by an internal aneurism or cancer on the recurrent nerve, no good can be done by electricity applied to the larynx; where it is owing to inflammation, ulceration, or morbid growths in the throat, a special local treatment by caustics, astringents, the *écraseur*, &c., together with constitutional remedies, has to be resorted to; but where the affection arises from mere loss of power in the muscles connected with the vocal cords, faradisation of the skin of the larynx, or of the suffering muscles, is the best treatment. Such loss of power is frequent in hysterical girls, but it also occurs after acute diseases, such as typhoid fever and diphtheria, after ague and rheumatism, in poisoning by arsenic and lead, in anæmia, from taking cold, through over-exertion of the voice, or a powerful impression upon the nervous centres, such as terror, fright, &c. In such cases the voice not unfrequently comes back after a time without any treatment having been resorted to; but there are numerous instances in which it does not return for years, and all treatment is unsuccessful, except the electric.

The first case of functional aphonia treated by galvanism has been recorded by Dr. Grapengiesser,[1] of Berlin, who applied the current of a single galvanic pair to the throat of a girl who had lost her voice for several years. He first vesicated each side of the larynx by blisters of the size of a shilling, and then applied the zinc pole to one of the excoriated spots and the silver pole to the other. The circuit was kept up for a quarter of an hour, during which time the larynx heaved convulsively, and a great quantity of serous liquid flowed from the sores. The sobbing continued after the metals had been removed, much mucus was expectorated, and two hours afterwards the voice was much more audible

[1] Versuche den Galvanismus zur Heilung einiger Krankheiten anzuwenden. Berlin, 1801.

and clear. After this process had been repeated several times, the voice was quite restored. Six months afterwards, however, it was suddenly lost again in consequence of a cold, and it did not again return, although the same process of galvanisation was repeated.

Since then all the different forms of electricity have been frequently used in the treatment of functional aphonia, and the results have on the whole been satisfactory.

An easy and successful method of applying electricity in these cases is faradisation of the skin of the larynx by fine wire brushes. I have on several occasions restored the voice by one such application. The current used must be of high tension. Dr. John Tanner,[1] of Newington Causeway, has practised faradisation of the tongue in this condition with good results. He places a moistened sponge conductor into the hand of the patient, and then touches the tongue with a metallic director. The patient at once screams violently, and thus convinces herself and others who are present that her voice has come back. He says that he has applied it in more than fifty cases, and always with the desired results. From his paper it appears as if one application had been found sufficient. Probably in all cases which came under Dr. Tanner's care the voice had been lost quite recently, for cases of long standing are not so easily cured.

In cases which resist such applications, intra-laryngeal faradisation should be resorted to. This method has yielded excellent results in the hands of Dr. Morell Mackenzie, while Prof. v. Ziemssen[2] expresses himself in more guarded terms concerning its value. He has obtained brilliant results in recent cases, but found those of long standing, even when incomplete and occurring in hysterical women, very obstinate.

[1] The Lancet, December 18, 1869.

[2] Deutsches Archiv, etc., vol. vii. p. 376.

Dr. Mackenzie[1] subdivides paralysis of the vocal cords into bilateral and unilateral paralysis of the adductor muscles, bilateral paralysis of the abductors, unilateral paralysis of one abductor, and paralysis of the tensors and of the laxors. Bilateral paralysis of the *adductors* of the vocal cords prevents approximation of the cords on attempted phonation, and consequently gives rise to loss of voice. Out of more than 200 cases of this affection which have been under Dr. Mackenzie's care, direct faradisation of the glottis has failed only in four, so that the proceeding seems to be almost a specific for the complaint. *Unilateral* paralysis of the adductors prevents the approach of one vocal cord to the median line, and gives rise to hoarseness or loss of voice. This is more difficult to cure, but also yields occasionally to faradisation. In paralysis of the *tensors* of the vocal cords, these are not properly stretched; the voice is lost or muffled, the higher notes more or less suppressed, and vocalisation is attended with a sense of fatigue or pain. In paralysis of the *laxors* of the vocal cords, the formation of the lower notes is interfered with, and the pitch of the voice is raised. Both tensors and laxors may be beneficially affected by faradisation, while in paralysis of the abductors electricity does no good. The following cases may serve to illustrate these different conditions:—

CASE 41.—*Bilateral Paralysis of the Adductors of the Vocal Cords.*

In May 1862, I treated an interesting case of this kind, together with Professor Czermak, of Prague, who had just then introduced the use of the laryngoscope into this country. A woman, aged 30, had lost her voice two months before, in consequence of a great emotion. An examination of her throat

[1] Hoarseness, Loss of Voice, and Stridulous Breathing, in relation to Nervo-muscular Affections of the Larynx. London, 1868.

showed that the adductors of both vocal cords were perfectly motionless and paralysed. Faradisation of the skin of the larynx was resorted to, and after two such applications, the patient could speak again, although still in a hoarse tone only. It was then discovered, by another examination with the laryngoscope, that the right vocal cord had, to a great extent, recovered its motion, but there was as yet no improvement in the left. By further treatment, the left cord was also brought back to its normal condition, and the voice entirely restored.

Case of unilateral paralysis of the adductors :—

C. E., aged 19, came under Dr. Mackenzie's care in June 1865. He had at the end of July 1864, suffered from a severe attack of diphtheria, and on recovering from the acute stage had experienced great difficulty in swallowing and loss of voice. Deglutition was now nearly normal, though he still had occasional attacks of coughing from 'things going the wrong way' whilst he was taking his meals. This was especially apt to occur in drinking. He had been taking iron, quinine, and strychnia, and for six weeks electricity had been daily applied to his throat externally. The voice, however, had not improved. A laryngoscopic examination showed slight paralysis of the adductors of the right vocal cord. Dr. Mackenzie faradised the affected muscle daily, from August 16 till September 10. By that time the patient was able to sound his voice, though he usually spoke in a whisper. Ten days later the *sound* of the voice was the rule rather than the exception, and by the middle of October the patient was able to speak in a strong, clear voice, which to strangers appeared perfectly natural, although he thought that 'it sounded differently to what it had done before his illness.' The action of the right cord now appeared normal.

14. *Difficulty of Deglutition.*—Where difficulty of swallowing is due to paralysis or spasm of the pharynx or œsophagus, faradisation and galvanisation are the best, and in many instances, the only means by which we can hope to cure this most troublesome and annoying affection.

Case 42.—Major I., aged 42, consulted me in September 1862, for loss of voice and difficulty of deglutition, brought on by an

attack of cerebral hæmorrhage which he had had in 1859, and which affected the entire left side of the body. For several months after this he had been so bad that his life was despaired of. He gradually, however, got better, and partially recovered the use of his arm and leg, while the voice and deglutition did not improve. The latter symptom even became worse as time went on, there being constant regurgitation, especially of fluids, which was very distressing. After a fortnight's faradisation the voice was so much improved that he could converse with ease, while swallowing was still difficult. I then applied a continuous current to the pharyngeal and œsophageal nerves, with the result that, after the second operation, a marked improvement was perceptible; and in a week the patient was able to swallow easily, without any regurgitation taking place.

M. Hiffelsheim[1] has recorded the case of a man, aged 26, who had suffered from acne, which was cured by arsenic, but who had otherwise been in good health. He had such difficulty in retaining his food, that most of what he took was returned as soon as it came into the pharynx, the liquids being rejected through the nose. In this case the continuous current was applied to the pneumogastric nerve. After three applications the patient could eat some roast meat and retain it; after five more he was quite well.

IV. SPASMODIC DISEASES.

Spasmodic diseases are much less amenable to electricity than paralytic affections; yet, in certain kinds of spasm, it deserves a trial when other remedies have failed. It appears probable that our modes of applying electricity in spasmodic affections are still defective, and that with an improved method better results would be obtained than is now generally the case. The methods principally employed at the present time are faradisation of the skin, and galvanisation of the affected nerves. Static electricity was

[1] Annales d'électricité médicale. 1862.

formerly much used in these cases, and seems to act much in the same manner as faradisation of the skin. As regards galvanisation, I am inclined to think that a much longer application than is generally resorted to for the treatment of paralysis is necessary for the cure of spasms.

1. *Chorea* is generally brought on by terror, fright, rheumatism, or intestinal derangement, and is frequently seen to disappear under the influence of cold affusions to the spine, strychnia, carbonate of iron, zinc, arsenic, &c., or even without any treatment. Labaume, Fabré-Palaprat, Addison, Golding Bird, and Sir William Gull, have treated chorea with static electricity, and have been well satisfied with the result. Dr. Bird has reported thirty-seven cases, thirty of which were cured, five relieved, one refused to continue the treatment, and only one was not cured. He applied static electricity to the spine, and affirms that the rapidity with which the patients were relieved was nearly proportionate to the facility with which the peculiar papular eruption on the skin took place. Sir William Gull, whose experience agrees with that of Dr. Bird, believes that the benefit is the result of a direct stimulation of the blood-vessels of the nervous centres, producing a more tonic and vigorous circulation in them.

Faradisation of the skin and of the suffering muscles is likewise beneficial in chorea. Children bear this operation remarkably well. It is not necessary to employ a strong current, a gentle application being sufficient.

Benedict has recommended to apply an inverse current to the spine, for a minute or a minute and a half continuatively, while Meyer recommends the intermittent application of the current to the suffering limbs. In the practice of the Infirmary for Epilepsy and Paralysis, where cases of chorea occur frequently, I generally use galvanisation and faradisation of the limbs alternately, together with gymnastic movements, whereby most cases recover in a short time.

2. *Scrivener's Palsy: (Schreibekrampf).*—The pathology of this peculiar and most troublesome affection is still enveloped in a considerable degree of uncertainty, although numerous theories have been put forward concerning it. Some observers believe it to be due to a simple spasm of the motor nerves of the hand, arising from over-exertion, while others look upon it as a reflex neurosis, originating, not from the nerves of the skin, but from the sentient nerves of the muscles used in writing. Others again consider

it a symptom of softening of the brain, or of granular disintegration of the vesicular neurine of the upper portion of the spinal cord.

Post-mortem examinations of uncomplicated cases of scrivener's palsy are as yet wanting, which is easily accounted for by the affection having no tendency to shorten life. In some cases where the nervous system has, after death, been examined, considerable degenerative changes have been discovered in the thalamus opticus and corpus striatum; but then there had been during life a whole train of symptoms foreign to true scrivener's palsy, and plainly referable to the anatomical changes just mentioned. Indeed, some patients suffering from scrivener's palsy ultimately die of hemiplegia, or other nervous affections; but quite as many of them succumb to kidney or liver disease, or to acute inflammatory disorders and other complaints, none of which bear any peculiar relationship to the affection which we are now considering.

In some diseases the efficacy of a particular mode of treatment, which was perhaps resorted to on purely speculative grounds, has given us valuable hints on the nature of the complaint for the cure of which it was used. But even this source of knowledge has until now been wanting as far as scrivener's palsy is concerned, for as yet no kind of treatment appears to have given uniformly satisfactory results. Rest has been largely prescribed, and is even now most strongly recommended by some of the best authorities; but in the majority of cases rest appears to be perfectly unavailing for the cure of the disease. Of course, as long as patients do not write, they are a great deal more comfortable than when they write much, or make futile attempts to do so; but how many return to their desk after a holiday of six, twelve, or eighteen months, during which they never touched a pen, only to find, to their grievous disappointment, that the rebellion of the hand against the mind continues just as strong as before!

It is certain that a purely medical treatment does no good in scrivener's palsy. Everything that appeared to have the least chance of influencing the course of the disease has been tried, more especially the so-called nervine tonics, such as nitrate of silver, arsenic, phosphorus, alone or in combination with iron and strychnia, bromide and iodide of potassium, &c., but without any avail. The usual recommendation of the handbooks to mprove the general health of the patient is no doubt well

meant, but can hardly be said to be useful, as the general health of the scrivener is almost always very good; and it seems hard to both physician and patient to give and take medicines which must be, to say the least, superfluous. Mechanical contrivances intended to procure rest to the fingers, and to allow the act of writing more with the arm than with the hand, generally prove useful only for a very short time, sometimes not longer than for a day or two; and after their use the suffering is generally rather more severe than it was before.

Local applications of liniments, embrocations, and ointments, whatever be their ingredients; hot, tepid, and cold local and general baths; gymnastic exercises; sea, mineral water, and carbonic acid baths, have all been tried and found wanting.

I am inclined to look upon scrivener's palsy as a symptom of fatigue and functional irritability of the co-ordinative centres in the upper portion of the spinal axis, which have by education been trained for the guidance of the mechanical act of writing, and which, on being by the mind called upon to act, put certain sets of muscles into harmonious, although unconscious, play for the performance of that act. Over-exertion of these ganglia must impair their nutrition, just as every other organ in the body has its nutrition impaired by over-exertion. Again, a constitutionally feeble condition of these ganglia may induce scrivener's palsy in persons who have never written much, and need not write unless they like. I have had two Peers under my care, who would unquestionably, and very fairly too, object to be called scriveners, but who, nevertheless, suffered from scrivener's palsy in an exquisite form. In one of them it was difficult to make out a family history of nervous affections, but in the other the following history was obtained:—His father was a fidgety, excitable man, who died early; his only full sister had for years suffered from an intractable form of chorea; his half-sister was subject to fits of depression. The patient himself, previous to the affection coming on, lived habitually highly, eating rich things, taking a full allowance of wine, besides being an active supporter of the turf, which often produced great excitement. Under such circumstances the affection may develop itself without any excesses in writing having taken place.

I cannot agree with Mr. Solly's[1] opinion, that the pathological lesion in these cases is a granular disintegration of the

[1] Surgical Experiences. London, 1865.

vesicular neurine of the spinal cord. If such severe anatomical changes really occurred in scrivener's palsy, it would be impossible to comprehend the immediate feeling of relief and improvement which is, in many cases, effected by one or two applications of the constant current. From looking at these facts, and also at the permanent recovery which can be obtained by a prolonged galvanic treatment such as will be presently described, I have arrived at the conclusion that there are much slighter changes of nutrition than Mr. Solly would lead us to assume, viz. constriction of the small arteries, dilatation of the veins, and slight serous effusions compressing the nerve-cells, and leading to imperfect nutrition of the same; that is to say, changes which we know to yield, if occurring in other organs, to the catalytic influence of the constant current, which produces a proper dilatation of the blood-vessels, and thus allows serous effusions to be absorbed, and the finer processes of nutrition to be fairly carried on.

That the motor nerves and muscles do not suffer in scrivener's palsy is evident to the most superficial examination. The muscles are often in splendid condition, and every simple movement of the arm and hand can be performed with the greatest ease. The patients generally say that there is nothing wrong with the hand itself, and offer to show you great feats of muscular power which they can accomplish with the hand and arm. They grasp your own hand with the power of a vice; they bang the table with force, and express their astonishment at there being so much power, and yet so little ability for that peculiar act which they desire above all things to accomplish, and which is to many of them of vital importance, as poverty stares them in the face in the event of their being obliged to throw up their employment.

In certain cases some other complicated acts, for which the skilful co-ordination of a number of muscles is required, appear troublesome. Some years ago I had a patient under my care who was an ardent admirer of the master works of the great classical composers, and whose only enjoyment after the monotony of a tedious day's work consisted in his evening's play of Handel, Bach, and Mozart. Six months after the first difficulty in writing had appeared, he found great trouble in executing a particular fugue which had been his great delight; and the discovery that his only pleasure in life would probably be taken

away from him, by the fingers refusing to obey the mind, made him more wretched than the thought about his position in life, which depended in a great measure on the use of his pen.

It follows from the preceding remarks that we can only hope for a really effective treatment of scrivener's palsy if we employ an agent which may directly influence the condition of those central ganglia which are affected in this disorder; an agent which must at the same time be tonic and sedative in its neuro-therapeutical effects; which must have the power of restoring the circulation of the blood in the suffering parts to its proper condition; which is capable of promoting the absorption of serous effusions, and will thus cause the nutrition of the maimed ganglia to be raised to its normal standard.

Such an agent we possess in the constant current, which appears to unite all the necessary therapeutical requisites for the cure of scrivener's palsy. Some German observers, such as Niemeyer and others, have cured patients of this class by a rough and ready application of the current to the nerves and muscles of the hand and fingers. The few successes obtained by a local application of the current do not clash with our theory of the central origin of the affection; for if one fact is well established in electro-therapeutics, it is this, that the continuous current, peripherally applied, has the tendency to travel towards the centres of the nervous system. For how could we, to mention only one circumstance, otherwise explain the sensation of galvanic taste which is so frequently experienced when the nerves of the arm or the leg are galvanised?

Local applications to the hand are vastly inferior to the central application of the current. The seat of the disease being in the upper portion of the spinal axis, one pole should be applied to the upper vertebræ; while the knowledge that the cervical sympathetic nerve has a powerful influence upon the nutrition of the whole nervous system induces us to apply the other pole to the ganglion cervicale superius. The direction of the current is by no means without influence upon the result of the application; for experience shows that the positive pole on the vertebræ, and the negative in the stylo-mastoid fossa, is the really curative arrangement, while the reverse flow of the current does not do nearly as much good. The current should be allowed to act from five to ten minutes at a time, and be applied to both sides if the left hand be also suffering. Twenty or twenty-five cells of Daniell's ba tery furnish sufficient power for this application. The almost

immediate relief from disagreeable sensations in the hand and arm which generally follows such a procedure is pleasant to the patient, and the ultimate cure which results, if the treatment be continued for a sufficient time, a source of gratification to the physician. As generally all other means fail to effect a cure in this most troublesome complaint, I cannot too strongly recommend practitioners to resort at once to galvanisation when the characteristic symptoms of scrivener's palsy have made their appearance; for the treatment is all the more rapidly successful the earlier it is employed after the commencement of the disease.

Where the application which has just been recommended does not answer, Dr. Poore's[1] plan of combining the application of the current with rhythmical exercise of the hand deserves a trial. He has recorded the case of a clerk, aged 32, who wrote a good hand and was constantly employed in copying balance-sheets. One day at the close of his day's work, he had a difficulty of bringing his right hand down upon the paper; but managed for some days after to write by holding his right wrist firmly on the desk with the left hand. After that he could no longer do anything, and had to leave his employment. He then learnt to write with the left hand, but this also gave way, and he could no longer earn his living. Spasms now came on in the right hand at other times; he could not use the knife at dinner, and broke a jug, in consequence of a sudden spasm, when about to pour out some water. The arm now became the seat of chorea, was always jerking about, and bounced out of the side pocket of his coat. When stripped, the deltoid, pectoralis maj., biceps, but more especially the triceps, were seen to jump; the arm was forcibly extended, and the triceps as hard as a board. The patient was enjoined rest, to wear the arm in a sling, and 15 grs. of Potass. Brom. *ter die*. This did him good generally, but did not diminish the spasm. A constant current was then applied to the deltoid, when the spasm at once subsided; and the patient was then made to elevate or depress his arm rhythmically, the doctor counting one, two, like a drill sergeant, and the patient keeping time to the counting. The pectorals were exercised by practising extension movements, and drawing back the shoulders; the fingers and thumb by opposing the thumb to every finger in turn, and by making him run on the table with his fingers, as on playing the piano. After these applications, the arm was no longer a nuisance to him. This was continued daily for

[1] The Practitioner, September 1872, p. 129.

several months. In August he could accomplish everything except writing with ease, and could also write tolerably well. It should be added that the patient also received a daily hypodermic injection of one-sixth gr. of morphia.

3. *Spasmodic Wry-neck, Torticollis, Caput obstipum*, consists of a convulsive affection of the spinal accessory nerve of one side, whereby the sterno-cleido-mastoid and the trapezius muscles are thrown into commotion. Electricity of high tension as a counter-irritant, and induction currents methodically applied to the antagonists of the suffering muscles, have effected amelioration or cure; but as the current must be very powerful if it is to do good, the continuous current appears preferable, its application being far less unpleasant. Where the emotional character of the disease is very marked, only little can be done by any treatment.

4. *Epilepsy.*—In certain forms of epilepsy, which resist other modes of treatment, the continuous galvanic current may do a great deal of good. Faradisation is, as a rule, useless in this disease, as it has no effect on the nervous centres; indeed, the only cases of epilepsy in which it has ever been of service have been those where the menstrual function was dormant or irregular, and where it proved valuable as an emmenagogue. The best mode of applying the continuous current is to cause anelectrotonus of the nervous centres, and of those peripheral nerves in the domain of which an aura is repeatedly or occasionally experienced. In a previous edition of this work several cases have been adduced showing the effects of galvanisation in epilepsy; but space prevents us from reproducing them here.

5. *Asthma.*—Dr. Hyde Salter[1] has spoken strongly against the employment of galvanism in this disease, and condemns 'the passing galvanic shocks through the chest.' He says that he has known this to do great harm; to bring on an attack in a patient at the time free from asthma; that it has, to his knowledge, aggravated existing spasm, but never done any good. Dr. Salter is at a loss to imagine what idea could have suggested the use of galvanism in asthma; but as he has taken great pains to prove that asthma is a nervous affection, depending upon a morbid condition, either of the pneumogastric or the brain, and not upon structural disease of the heart or air-passages, I am surprised at Dr. Salter's reasoning. I could understand his anathema against galvanism in asthma, if that disease were due

[1] On Asthma: its Pathology and Treatment, p. 317. 2nd edit. 1868.

to bronchitis, emphysema, or heart-disease; but as he has shown it to be owing to spastic contraction of the unstriped fibre-cells animated by the pneumogastric nerve, galvanisation of that nerve would appear to be a most rational mode of treatment. The best proceeding is to cause anelectrotonus of the pneumogastric, with which faradisation of the phrenic nerve may be combined. The latter answers best in chronic cases, where the asthmatic attack is prolonged, and followed by bronchial congestion, with insufficient expansion of the thorax and imperfect aëration of the blood.

6. *Shaking Palsy.*—Trousseau speaks of paralysis agitans as an absolutely incurable disease, and this, I believe, is even now true for cases of long standing. If the affection be confined to one limb, and the case be recent, anelectrotonus of the medulla longata and the spinal cord is occasionally of service.

Dr. Russell Reynolds[1] has cured a case of paralysis agitans of the right arm, which had come on suddenly in a man aged 57, who had for two years before suffered from occasional tremor of the right arm and leg. He used the current of 120 links of Pulvermacher's chain battery to the arm, for half-an-hour or an hour each time. There was improvement after the first application, and after five the spontaneous jactitation completely ceased. The fact of the palsy having only lasted a fortnight, and being confined to one limb, would naturally make the case a most favourable one for galvanic treatment.

7. *Tetanus.*—Dr. Mendel,[2] of Berlin, has recorded the case of a girl aged 4, who had been run over by a cart on May 17, 1868, and suffered comminutive fracture of both phalanges of the right thumb, as well as some minor injuries. The father of the child dressed the wound himself, and when, eight days afterwards, the crushed finger was only connected with the hand by a small bridge of skin, he cut this through. The general condition of the child appeared then satisfactory. Six days afterwards, however, difficulty of swallowing came on, the teeth could not be separated, and the muscles of the neck became rigid. A centigramme of opium was given every two hours, without any result; on the contrary, tetanus became developed, fresh sets of muscles being successively seized by clonic contractions, while those previously affected remained in tonic contraction.

[1] The Lancet, 1859. Vol. ii. p. 558.

[2] Berliner klinische Wochenschrift, Sept. 21, 1868.

On June 12 the little patient had a pulse of 132, the temperature in the rectum being 103·5° Fahr. She was lying on her back, moaning and coughing alternately; could neither sit nor walk nor stand, and only sit up in bed with much trouble, and convulsions. The head was strongly retroflexed; the face livid and slightly œdematous; the pupils slightly dilated. The masseters and temporal muscles were tetanically contracted on both sides, so that only the handle of a spoon could with difficulty be inserted between the teeth; on the tip of the tongue some abrasions were seen, probably from the impressions of the teeth. A few herpetic vesicles were noticed on the edge of the right side of the lower lip. The right thumb was absent; on the right hand there was, above the os metacarpi pollicis, which was preserved, a wound of the size of a bean, covered with abundant granulations. The hand was flexed at a right angle, and slightly supinated; the fingers were flexed. It was impossible to change the position of the hand or the fingers, even if great force was used. The muscles of the fore-arm and arm were rigid, while the left arm was in its normal condition.

The trapezii, on both sides, but more especially the right one, were rigid and swollen; the head could not be moved to either side; the muscles of the back, more especially the right rhomboides major, were tonically contracted. The muscles of the abdomen were in their usual condition, but those of both thighs harder than usual; both feet, more especially the right, had assumed the highest degree of pes equinus. The muscles of the calf were as hard as a board; the position of the foot could not be altered by employing mechanical force. Whenever the body was somewhat strongly touched, opisthotonus ensued.

An examination of the chest showed, to the right and posteriorly, moist sounds, which were more feebly perceptible anteriorly. The left lung was not affected. The urine, which was scanty and passed into bed, contained a large amount of urates, but neither albumen nor sugar. There was some constipation. The constant current was now used, and all internal remedies were omitted. The anode of a battery of eight cells of Krüger and Hirschmann (Daniell's) was applied to the external side of the right fore-arm, and the negative to the cervical spine. Almost immediately after closing the circuit it was possible to move the hand freely in all directions; the tetanus in the muscles of the fore-arm having for the time disappeared. The

anode applied in the same manner to the muscles of the left calf, and the cathode applied to the lumbar spine, appeared to have no effect on the muscles, the ankle-joint remaining fixed. The anode was then applied to the anterior part of the leg, close above the joint, after which the foot was easily movable in every direction. The same proceeding was repeated on the right leg. When the anode was placed upon the tetanic muscles, no effect was produced, but on being applied to the front of the leg, the tetanus ceased at once. The muscles of the jaw did not yield so readily, although the anode was successively placed on various points of the face; and only when it was directed to the left infra-orbital nerve, the mouth could be opened a little further. The electrodes having afterwards been applied to the muscles of the neck, the tetanus ceased there likewise, and the head became movable in every direction.

The whole application lasted about fifteen minutes, and the muscles remained relaxed after the application. On the following day, the improvement continued, there was greater flexibility of all the muscles of the extremities; neither the flexors of the fore-arm, nor the gastrocnemii were as rigid as before; the position of the head and back was better, and the mouth was so far opened that a finger could be inserted between the teeth. The joints were, however, somewhat stiffer than they had been immediately after the first application. The induced current was now used, in order to see whether this would have any effect, but the muscles remained exactly in the same condition as before, and the irritation produced fresh reflex spasms. The little patient was now again treated with the constant current, as on the preceeding day, and the same result, viz. immediate relaxation of the rigid muscles, was obtained.

The day after (June 14) the pulse had gone down to 112, and the temperature to 99·3° Fahr. The child had slept at night, the cough and other symptoms of bronchitis were less; there was some appetite; the mouth was so far open as to allow the introduction of the thumb. There was still slight rigidity in the muscles of the right fore-arm, and both legs, but some little force was sufficient to overcome it. The position of the head and back was satisfactory. The constant current was again used.

June 15.—The child had had a good night, had eaten a roll, could put her feet to the ground, and had walked a few steps on being supported.

June 16.—The general condition much improved.

June 17.—The head was freely movable in every direction; the tongue could be put out; the child could stand upright. The muscles of the back and the extremities were soft and flexible. There was some œdema round the ankles. General condition satisfactory. Galvanisation repeated.

June 18.—Sleep and appetite good; the fingers of the right hand still slightly contracted and flexed. No trace of tetanus left; galvanisation repeated for curing the contraction of the fingers. Within a week this result was likewise obtained. In this case the relief caused by the application of the constant current was so immediate and decided, that no doubt about the real efficacy of the remedy could be entertained.

Dr. Mendel has also recorded a case of idiopathic tetanus in a girl aged 11, in which the constant current, within ten days, completely overcame the affection. In this case he found that when the anode was placed to the second or third lumbar vertebra, and the cathode to the sternum, the abdominal muscles were at once relaxed. He recommends the use of a gentle current, the anode being directed to the antagonists of the affected muscles. The current thus applied seems to act rather on the sentient than on the motor nerves, for no contractions are visible, while the excessive irritability of the sentient nerves is subdued.

Onimus and Legros[1] have been equally successful in a bad case of traumatic tetanus; but it is not so convincing as Dr. Mendel's, because large doses of hydrate of chloral were given at the same time. In this case the wound was inflicted by a circular saw, which opened the joint formed by the first and second phalanges of the left thumb. Symptoms of trismus appeared ten days afterwards, and were followed by tetanus. Digitalis, chloral, and bromide of potassium were given, and the patient got rather better; but as he continued in a bad condition seventeen days after the injury, the muscles of the neck, chest, and abdomen being strongly contracted, and respiration purely abdominal, anelectrotonus of the cord was produced, the application lasting forty-five minutes. The contracted muscles became almost immediately relaxed, and respiration became thoracic. The patient was constantly kept under the influence of chloral, and slept almost the whole time of his illness. On one occasion

[1] Loc. cit. p. 408.

he had a fainting fit; respiration and the heart's action ceased for a whole minute, and he was covered with a cold sweat; the current was at once applied to the spine, and respiration, at first stertorous, as in an epileptic, became gradually re-established; the pulse, which had disappeared, returned, beating eighty-eight times in the minute. The current was generally applied once or twice a day for an hour or even two hours at a time for fifteen days, after which the patient was convalescent.

8. *Hydrophobia.*—Several Italian authors have, in the commencement of the present century, published cases of hydrophobia cured by galvanism; but these records are worthless. More recently Signor Schivardi[1] has published a case of this disease which was treated under the supervision of a committee of medical men in Milan appointed to study hydrophobia, and of which the following is an abstract:—

A girl, aged 9, was bitten by a suspicious dog on March 15, 1866. There were three wounds on her head, and one on the right hand, which were not cauterised, but merely treated with an ointment, and healed spontaneously. The first symptoms of hydrophobia came on on April 27. Two days afterwards she was received into the hospital. The committee agreed that the continuous current should be used, and the cathode of twenty-two cells of Daniell's battery was applied to the forehead, the anode being directed to the feet.

This current, which deflected the needle to an angle of 34°, was for four days uninterruptedly sent through the body of the patient(?). The result was that the pulse became more quiet, the patient slept, and the throat-spasms decreased so much that she could eat and drink again. On the sixth day of the disease, after eighty hours' galvanisation, the girl had lost every symptom of hydrophobia, and electricity seemed to have mastered the disease; but the patient was now in a state of prostration and somnolence. The committee refused to administer stimulants. The weakness increased during the next few days. The pulse became rapid, there was profuse perspiration, no appetite, loss of consciousness, diminished quantity of urine, which was alkaline, and a rod with hydrochloric acid approached to the mouth of the patient was covered with white fumes. She died seven days and seven hours after the first symptoms of hydrophobia had set in, of uræmic poisoning of the blood.

[1] Gaz. med. ital. Lombard, No. 22, 1866.

Signor Schivardi thinks that this patient might have recovered if stimulants had been given; but this, of course, is only an opinion. The *symptoms* of hydrophobia were evidently relieved, but the poison killed the patient just as well as if no treatment had been adopted. This would be analogous to the case of Ranke's frogs, which, after being poisoned with strychnia, could be kept free from convulsions by the use of the continuous current, but died nevertheless of the systemic effects of the poison.

9. *Stammering.*—The best mode of treating stammering is systematically to educate the vocal and respiratory organs; but the continuous current may be of service in conjunction with it.

Case 43.—An intelligent boy, aged 9, one of ten children, was sent to me in January 1868. His general health was tolerably good, but ever since his fourth year he had suffered from defective speech. He could only talk fluently when he was excited, but otherwise he stammered very much. He complained of headache and occasional dizziness, and the pupils were excessively large. Having some suspicion of masturbation, I examined the sexual organs, and found a high degree of congenital phimosis which appeared to produce considerable irritation. I therefore, before resorting to any further treatment, sent him to Mr. Curling to be circumcised, which was done in February 1868. In consequence of this operation the general health improved, but the spasm in the throat remained as bad as ever. I therefore now applied the continuous current to the laryngeal nerves continuatively, giving at the same time directions for a gymnastic education of the voice. After two months' treatment, the patient attending twice a week, he was very much improved; and when I saw him again four months afterwards, he spoke as well as could be wished.

10. *Facial spasm: (histrionic spasm, tic convulsif.)*—This affection, which is owing to irritation of one or several branches of the fifth pair of cerebral nerves, resists all purely medicinal treatment. Neurotomy of the portio dura, which has sometimes been performed for the cure of it, I should consider bad practice, as it produces paralysis instead of spasm, the former being a greater inconvenience than the latter. On the other hand, the excision of a small piece from that branch of the fifth nerve, the irritation of which produces the spasm, generally cures the

complaint, without paralysing the muscles of the face. The ulterior consequences of neurotomy of branches of the fifth nerve in such cases are not yet well known; but as it is almost always either the supra-orbital or the infra-orbital nerve which has to be divided, it is to be feared that the nutrition of the eye may suffer in consequence of such operations. It would therefore be very desirable to have a less severe mode of treatment at our disposal.

The continuous galvanic current, applied to the branches of the fifth nerve, generally improves the spasm; but seems to cure only cases of recent standing. I have never yet succeeded in curing one of more than twelve months' duration; while Remak[1] and Benedict appear to have succeeded better. In some cases a continuative, and in others an intermittent, application answers best; and voltaic alternatives appear to be useful.

V.—ANÆSTHESIA.

Anæsthesia may arise from disease of the brain, spinal cord, or peripheral nerves, and is either complete or partial. In some cases all the different kinds of sensations are lost, but in others only one or two of them are gone, while the others remain intact. Thus common sensation may be impaired or lost, while the senses of temperature and locality are as acute as ever, &c. In most forms of anæsthesia an electric treatment is of service. Where the affection is due to effusions compressing the nervous matter, the continuous current appears to be most effective; but where it occurs from want of nervous power, more especially in hysteria, faradisation of the skin or static electricity are likewise applicable.

1. *Anæsthesia of the Cerebral Nerves.*

a. *Loss of Smell* (*anosmia*).—Total loss of smell is rare, and its pathology still somewhat obscure. In some cases it appears to be due to cerebral disease, while in others the olfactory nerve is compressed by tumours, exostoses, and effusions.

In three cases observed by Dr. W. Ogle[2] the affection occurred after accidents, and was owing to rupture of the olfactory

[1] Berliner klinische Wochenschrift, No. 22. 1864.
[2] Medico-Chirurgical Transactions, p. 263. 1870.

nerves on their way from the bulb through the holes in the ethmoid bone. Bertholon has recorded a case of anosmia consequent upon rheumatism, and which was cured by static electricity. Kreyenhoff obtained a similar good result in a case of hemiplegia, complicated with loss of smell. Duchenne mentions that he has frequently used faradisation of the mucous membrane of the nose for restoring the lost smell, and has generally been successful. I have seen a case of anosmia which came on in a gentleman, aged 39, without any apparent cause. He was of a strumous constitution, and said that as a boy he had been constantly bled, leeched, and mercurialised. He never had had syphilis, nor had he been subjected to any accident. There was a general want of tone, with a slow pulse (mostly 58.) I gave him iron, and applied the continuous current by means of a nasal conductor to the Schneiderian membrane. After a few such applications, he smelt Eau de Cologne and other perfumes, which he could not smell before.

b. *Amblyopia*; *amaurosis*; *weakness of sight from imperfect nutrition of the optic nerve.*—Amaurosis was much more frequently diagnosed before the introduction of the eye-mirror into ophthalmic practice, than it is at present. Von Graefe[1] excludes from this denomination all disturbances of sight dependent upon material changes in the refractive media, in the internal tunics of the eye, and also neuro-retinitis and embolism of the central artery of the retina. He confines the term amaurosis to cases of blindness from primary or degenerative atrophy of the optic nerve, while he understands by 'amblyopia' that impairment of vision which is produced by irregularities in the circulation, and which may in the end lead to primary atrophy of the optic nerve.

The medicinal treatment of these affections generally yields only little result. The various forms of electricity have often been used, and sometimes with advantage. De Saussure obtained a cure of amaurosis by shocks of static electricity directed from the eye-ball to the neck; while Magendie and Person were successful with magneto-electricity. M. Lesueur[2] has recorded a case of complete amaurosis, but where the mobility of the iris had not suffered, and which was nearly cured by electro-magnetism. He applied one moistened conductor to the closed eye, and the other to the neighbourhood of the orbit, the neck, and

[1] J. Soelberg Wells's Treatise on Diseases of the Eye, p. 396.

[2] Journal des Connaiss. méd., 10 mars, 1861.

the scalp. The operation lasted four minutes. The patient discontinued the treatment before she was quite cured, but at the end of it she could read a test-type three millimètres high. Unfortunately M. Lesueur did not examine his patient with the ophthalmoscope, so that we have no accurate information on the nature of the disease.

Mr. Dunn,[1] of Crick, Derby, has recorded a case of loss of sight in a servant girl, aged 15, free from symptoms of hysteria, who, while engaged with her work, fell and struck her eye upon a round knob of the stair balusters. The eye became much swollen and inflamed. The patient could see imperfectly after the accident, but the following morning she was totally blind on the injured side. Mr. Dunn saw her three weeks afterwards, when the eye looked perfectly healthy, all traces of inflammation having disappeared. Supposing it to be a case of concussion and subsequent paralysis of the retina, he passed a gentle magneto-electric current through the eye, using his finger as electrode. An immediate improvement took place; the sight gradually returned, and in five minutes the girl read large capitals with the affected eye. Faradisation was twice repeated, and after the last application one eye was as good as the other. In this case also no ophthalmoscopic examination of the eye was made.

Duchenne recommends faradisation for amaurosis; but the continuous current would seem to be preferable on account of its powerful physiological action on the optic nerve. It has not yet been fairly tried, and it appears, therefore, very desirable that a systematic use of it should be made in one of our numerous ophthalmic hospitals, in order to lead us to definite conclusions about its actual value. An examination of the eye by means of the ophthalmoscope should always precede the galvanic treatment.

Dr. Pye-Smith[2] has treated a series of cases in Guy's Hospital, in which an ophthalmoscopic examination had been made. He used between ten and twenty cells of Daniell's battery, the electrodes terminating in small sponges soaked in warm water. The cathode was placed on the skin behind the ear, and the anode to the closed eyelid of the same side or to the brow. Ophthalmoscopic examination during the passage of the current showed in all cases the veins of the retina to be congested after the first

[1] The Lancet, November 1867.

[2] Brit. Med. Journ., May 18, 1872.

second (during which they sometimes appeared to be partially emptied), and to remain so till the interruption of the circuit, when they gradually resumed their natural fulness. This effect was observed even when no flash was perceived by the patient.

The patients were galvanised every Tuesday, Thursday, and Saturday. The current was usually passed six times at each sitting, for eight or ten seconds each time, with intermissions of an equal period.

On closing the circuit with ten cells, the healthy eye perceived a round central illumination of the size of a sixpence, irregularly circular, and of a blue tint. The impression lasted about five seconds, and then gradually faded away. On interrupting the circuit, a momentary flash was perceived over the entire field. These effects were more marked when the eyes were shut.

The number of cells employed was determined by the flashes perceived, the smallest number being used that produced in each case any illumination; and where no flashes were perceived, an unbearable amount of burning at the electrodes, or the occurrence of giddiness, served to limit the number.

The following is one of the cases recorded by this observer :—

J. I., aged 42, a wheelwright, was admitted December 12, 1871. His general health was good, except for an attack of quotidian ague twelve years ago. He had been in the habit of smoking about two ounces of shag per week. His sight began to fail nearly five years ago. He went to the Ophthalmic Hospital, and attended as an out-patient for three years, taking medicine daily. The sight continued to fail during this period, but the patient was able to keep at work till the end of that time, and, till the last few months of it, to read. He frequently had severe occipital headache. He came to Guy's Hospital as out-patient nearly two years ago, when both optic discs were found to be white; he had attended ever since, giving up smoking, and taking one-third of a grain of pilula opii three times a day. His sight had continued to become worse. During the last year he had felt ill and nervous. Since his sight began to fail, he had had about half-a-dozen attacks of frequent shivering followed by vomiting, lasting for a day or two, and then passing off. On admission he was very tremulous. He could just distinguish windows with each eye, but could not count the panes. He considered the right his best eye. He stated that he saw best in a dull light, and that he was able occasionally to see the time by a large clock for a minute or two,

and then the sight became dim again. The tension of the right eye was slightly above the normal. The pupils were dilated and sluggish. On ophthalmoscopic examination both eyes were found hypermetropic. The right optic disc was well-defined, bluish-white, with very white centre; its vessels were slightly displaced to the nasal side; the arteries were small and few. The left optic disc was well-defined, bluish-white; the arteries were very small and few; the veins few and half empty. The retina was rather anæmic. There was a small floating opacity in the vitreous body. Both eyes were galvanised twenty-three times —*i.e.* on twenty three different days; each day, as before stated, the current was passed about six times through each optic nerve. A battery of twenty elements was used. A flash was usually perceived on closing the circuit, and a 'dark flash' on interrupting it. Occasionally slight headache was produced, but the trembling disappeared in a week or so. After the fourth application the patient was able to see the seats in the grounds; after the seventh he could count the panes of a window upwards, but not from side to side; after the seventeenth application he was able to read 'Operation Room,' painted in letters about three inches high over a door in the ward. He could now always see the time by a large white-faced clock, and could see his way about the grounds much better than at first. On January 18 he was seized with one of his attacks of vomiting, shivering, and loss of appetite. The sight was a good deal impaired for several days, but the galvanism was continued, as he was very anxious for it. His sight was examined again on January 31. He could now see the paths in the grounds, people as he met them, a white stone sun-dial out of doors, the time by the clock, and could count the panes of a window in both directions with either eye. Ophthalmoscopic examination showed no marked change. (See table on p. 588.)

Mr. Kiddle has, in the same hospital, tried the effects of the continuous current on five female and six male patients, and has obtained entirely negative results. This is so contrary to my experience, that either the worst cases must have been selected, or the method of application have been injudicious.

My own experience in anæmia of the optic nerves is that most cases improve, but I cannot boast of a single cure. I believe that the results will eventually become better than they are now, because galvanisation will be resorted to at an earlier stage of the complaint than is generally done now, and because I hope

The following table may serve as an analysis of Dr. Pye-Smith's cases.

Case	Duration of amblyopia	Eye galvanised	No. of elements employed	Description of flashes perceived	No. of days galvanised	Result	Remarks
1	2 to 5 yrs.	Both	20	Momentary flashes on closing and on interrupting.	23	Considerable improvement.	
2	2 to 3 yrs.	Both	15	Momentary flash on interrupting.	18	Doubtful improvement.	
3	2 to 3 yrs. (still slight.)	Left	10	Normal illumination and flash.	11	Sight impaired.	Case complicated by results of syphilitic inflammation, and (?) of Bright's disease.
4	½ to 2½ yrs. (still slight in right eye.)	Both	15	Right, normal illumination. Left, none.	20	Doubtful improvement.	
5	2 to 3 yrs.	Both	15	None.	5	None.	Treatment not continued long enough to obtain any result.
6	½ to 1½ yrs.	Both	15	Momentary flashes on interrupting & sometimes on closing.	17	Slight but decided improvement.	Case complicated by results of syphilitic inflammation.

that our mode of conducting the treatment will be more effective. It is of no use to continue the treatment indefinitely, but the current should be used daily, or at least four times a week, for a month. It should then be discontinued, and a month's interval allowed, after which it should be resumed in the same manner as before. I think Dr. Pye-Smith has applied the current too short a time, five or six minutes being, according to my experience, better than one minute.

In *weakness of sight*, without structural lesions, and which might perhaps merge into amblyopia or amaurosis if allowed to go on unchecked, the constant current often produces excellent results. I have seen a number of such cases which were due either to over-exertion of the eyes in reading and drawing, or to the general malnutrition of advancing age, and in which the gal-

vanic treatment rapidly restored the eyesight to its normal strength. Some of these cases were complicated with photophobia, which yielded to the same remedy.

c. *Loss of Taste* is generally due to an affection of the third branch of the fifth, or of the glosso-pharyngeal nerve, or the chorda tympani; and if remediable, yields to the influence of the continuous current.

d. *Nervous Deafness.*—Cases not unfrequently occur in which there is a defect of the power of the brain or the auditory nerve to receive or appreciate sounds, without any physical alterations of the organ of hearing. Such may be properly called cases of 'nervous deafness.'

The affection is often accompanied by general debility, and seems to arise from causes which have a tendency to weaken the tone of the nervous centres, such as grief, anxiety, sleeplessness, over-exertion of mind or body, and exhaustive discharges. I have likewise seen it come on during convalescence from acute diseases, such as typhoid fever. Nervous deafness yields sometimes to galvanisation or faradisation.

M. Bonnafont[1] has recommended electro-puncture of the membrana tympani for cases of nervous deafness. He illumines the membrane by means of a speculum, and then introduces a fine acupuncture needle towards the anterior part of it, until it meets with an impediment. A small piece of cotton-wool is then put into the meatus, in order to keep the needle in its proper position. After this, a silver canula is introduced into the eustachian tube, where it is fixed with a forceps; and a fine silver wire is then inserted into the canula, which is insulated everywhere except at its two ends, one of which serves as electrode, while the other receives one of the conducting wires; magneto-faradic shocks are then given.

Dr. H. Campbell[2] recommends to apply the constant current for accumulation of mucus in the middle ear, which is caused by aural catarrh and followed by deafness. A fine copper wire, insulated except at its extremities, is introduced through the eustachian tube into the cavity of the tympanum, which has been previously injected with warm water, and a gentle current applied to the contents, which are quickly decomposed by the

[1] Traité théorique et pratique des maladies de l'oreille et des organes de l'audition. Paris, 1860.

[2] Electro-Surgery. London, 1872, p. 23.

electrolytic action. At the same time the condition of the mucous membrane is so altered that there is no tendency to relapses.

2. *Anæsthesia from imperfect Cerebral Nutrition* is often cured by the continuous current :—

CASE 44.—A gentleman, aged 64, widower, accustomed to generous living, suffered two years ago from a severe cold and indigestion, after which he was frequently troubled by an unpleasant sensation of numbness and coldness in the left thigh. Of late he had had the same feeling of cold, heaviness and numbness in the left side of the head, especially after a chill; and walking had become rather troublesome. The memory was good, and although the patient had given up active occupation, there was no deficiency in his power of application, whenever it seemed to be required. There was a well-marked arcus senilis, and the sense of smell was defective. My opinion on this case was requested by Dr. Allen, of Hyde Park Terrace, in July 1866. We agreed that the symptoms could only be due to want of cerebral power in the right hemisphere, and that the continuous current should be used. I applied fifteen cells to the head, and thirty to the thigh, with voltaic alternatives. After four such applications, the sensation of numbness, heaviness and cold about the head, was gone, and two more also relieved the anæsthesia of the thigh.

3. *Hysterical Anæsthesia*

Hysterical women often suffer from a sensation of numbness, which is sometimes fixed in a limb, or part of a limb, but in other instances migrates about the body. Cases of this kind are generally curable by faradisation. In November 1857, an hysterical woman, aged 36, was sent to me by Dr. Henry G. Wright; she complained of numbness in the nape of the neck, the dorsal spine, and both arms. I applied the induced current to the parts mentioned, and when I saw the patient the following day, she stated that she had nearly regained the normal feeling in them: three other applications effected a cure. In other instances, however, a longer treatment may be required.

CASE 45.—A. C., aged 28, married, was in July 1857 admitted into Carlisle ward, St. Mary's Hospital, under the care of Dr. Alderson. Three years ago she had suffered from rheumatism. Fifteen months ago the first symptoms of her present illness appeared; walking became difficult, she did not feel the ground,

and suffered from numbness in the back and the lower extremities. She had never had cramps or twitches in the leg. She had been treated by cuppings, leeches, and blisters along the spine, strychnia, calomel, and galvanism. When I first saw her, soon after her admission, the skin of the face, neck, and arms was duly sensitive, but on the back there was complete anæsthesia from the seventh cervical vertebra down to the sacrum, and the same was the case with the lower extremities. In walking she staggered, and the muscles of the lower extremities responded very little to the faradic stimulus. There were no symptoms of disease of the womb, bladder, and rectum. In order to restore the lost vitality to the sentient nerves, I faradised the skin of the back and of the lower extremities with wire-brushes. While in the normal state of the nerves the faradic stimulus is felt as soon as applied, this patient did not feel it until it had been applied from five to six seconds. Such was the case on the back as well as on the lower extremities; but in the soles of the feet no sensation could be produced even by a most powerful current. I continued faradisation, and after six applications the sensibility of the back had become nearly normal. The sentient nerves of the lower extremities were more deeply impaired than those of the back, and it took a longer treatment to effect an improvement in them. The patient walked much steadier when she left the hospital, although she had not quite recovered.

4. *Anæsthesia from Effusions, or Injury to Nerves.*

CASE 46.—A gentleman, aged 62, unmarried, came under my care in November 1867. Three months ago he had had a sharp attack of gout in the right foot, which subsided after six weeks' treatment, when he first began to walk about with the aid of a stick. He then found that he had almost entirely lost the feeling in the sole of the foot, the ankle, and the knee-joint. He used liniments, and the leg was rubbed and shampooed, but with no effect. He now complained of a sensation of numbness and loss of power in the leg. The prick of a pin was not felt between the foot and the knee-joint, and even in the thigh it was felt less than in the thigh of the other side. There was still some tenderness in the big toe and the ankle, but no waste of muscular tissue. The leg was colder than the left, and the sense of temperature was completely gone. The patient had six applications of the

continuous current intermittently to the nerves and muscles of the thigh and leg, after which he had recovered the sensibility and the use of the extremity.

The following case, which was due to injury, occurred in Remak's practice :—

A woman had injured the second phalanx of her left thumb with a hatchet. After the wound was healed, the top of the thumb remained insensible and numb. Within a twelvemonth the numbness progressed from the cicatrix to the back of the arm, along the course of the radial nerve, and in front along the course of the median nerve to the elbow; and it gradually thence crept up to the neck and the left cheek. On these latter places and on the back of the arm it disappeared again after a time, but increased in the course of the median nerve, and especially in the tips of all the fingers. A current of from fifty to seventy cells of Daniell's battery was applied to the cicatrix only, and the sensation in the thumb and the other fingers was restored after four such operations.

VI.—ASPHYXIA AND SYNCOPE.

Hufeland[1] first proposed the application of electricity to the phrenic nerve in asphyxia of newly-born infants, one pole being directed to the cervical vertebræ, and the other to the pit of the stomach ('ut iter nervi phrenici sequamur'). The same idea occurred sixty years later to Dr. Marshall Hall;[2] but neither Hufeland nor Hall seem ever to have carried out their plan. In 1848, Jobert de Lamballe and Ducros made a number of experiments on chickens, pigeons, and other animals, in which anæsthesia by ether or chloroform had been produced, and which were readily roused by the application of the induced current. Duchenne[3] recommended, in 1855, localised faradisation of the phrenic nerves for the cure of asphyxia; but Ziemssen[4] was the first who, in 1856, used this method successfully.

A servant-girl, aged 27, was found in her bed early one morning, asphyxiated by charcoal-fumes. Counter-irritation of the skin proved unavailing in inducing respiration; and when

[1] De usu viris electricæ in Asphyxia. Gottingæ, 1783.
[2] On the Diseases and Derangements of the Nervous System. London, 1841.
[3] De l'électrisation localisée, p. 738.
[4] Die Electricität in der Medicin, 1st edition, 1857, p. 49.

Ziemssen was called in, the pulse and respiration were almost imperceptible; the skin was getting pale, the temperature of the extremities low, and the râles in the trachea more marked. The phrenic nerves were now rhythmically faradised, when the chest was seen to expand, the girl began to cough, the cheeks showed a faint flush, and the extremities became warmer. Faradisation was continued, with short interruptions, for two hours, when respiration was fairly re-established. Eleven hours afterwards respiration was regular, and the patient was quite well the next day.

Friedberg[1] has been equally successful in a case of asphyxia in a boy aged 4, who was placed under the influence of chloroform in order to have a cyst of the eyelid removed. After a few inhalations the pulse suddenly became small, the face livid, the eye glassy, the limbs relaxed; one short râle was heard, after which respiration ceased. Cold water was rapidly thrown on the face and chest, ammonia held under the nose, and the larynx tickled with a sponge. After this had been done for two or three minutes, the pulse became imperceptible, the complexion pale, the lower jaw dropped, the expression of the face was cadaveric, and the pupils dilated. Artificial respiration by methodical compression of the abdomen was then resorted to for three minutes, but likewise without any result. Dr. Friedberg now faradised the diaphragm by putting one electrode to the phrenic on the neck, and the other into the seventh intercostal space, for one second at a time. After ten such applications, the first inspiration took place; faradisation was then discontinued, and a second and third inspiration were seen. After the third, the radial pulse re-appeared, and further methodical compression of the abdomen was now sufficient for re-establishing respiration and the heart's action. In twenty minutes the child had fairly recovered. The operation was then performed, and the little patient slept for an hour; after which he appeared perfectly well, and no further effects of the chloroform were noticed.

Ziemssen[2] has used faradisation of the phrenic nerves in four other cases successfully; the asphyxia being due to poisoning with carburetted hydrogen gas, charcoal-fumes, and to freezing after alcoholic intoxication. In five other cases which came under the care of the same observer, the proceeding failed to do

[1] Virchow's Archiv, vol. xvi. p. 527. 1859.
[2] Die Electricität, etc., 3rd edition, p. 180.

good. Oppenheimer[1] has been unsuccessful in a case of opium-poisoning, although he continued faradisation for three hours. Mosler and Möller have likewise published unsuccessful cases. Pernice[2] has used faradisation in five cases of apparent death in newly-born infants; in two of these the result was *nil*, while in three life was restored.

Dr. Hardie,[3] of Manchester, has restored life in two similar cases by faradisation of the phrenic nerve. One was that of a boy aged 10, who was operated upon for a cyst on the shoulder-blade, and who during the operation suddenly ceased to breathe, nor could the pulse be felt. He had a livid appearance, which soon passed off into pallor. Cold affusion and artificial respiration having been tried and failed, the aspect of the patient seemed very hopeless. Faradisation of the phrenic was now practised by Dr. Gumpert, upon which slight and very superficial respiration occurred, and the heart's movements became visible. In three quarters of an hour the child was out of danger.

In another case, that of a woman aged 42, who was operated upon for secondary cancerous deposit in the axillary glands, Dr. Hardie was dissecting out the glands when the respiratory movements ceased without previous stertor or other warning; the patient's face assumed a death-like pallor with slight lividity; the eyes were staring and the pupils widely dilated; the pulse immediately afterwards became imperceptible. The tongue was at once drawn out, but without response on the side of the respiration. The electrodes of a volta-faradic apparatus were applied to the root of the neck over the phrenic nerves (cold affusion and a few acts of compression of the chest having in the meantime failed to induce respiration). For a time there was no response, and the patient's condition seemed hopeless. At length, however, a short gasp came, then others, which soon became deeper and regular; the pulse became perceptible, the colour returned to the face, and the pupils contracted. Dr. Hardie considers that the boy was dead three minutes, and the woman one; and he recommends every practitioner to make a faradic apparatus the invariable companion of his chloroform bottle.

[1] Lehrbuch der physicalischen Heilmittel, Heft i. p. 157.
[2] Greifswalder medicinische Beiträge, Band ii. p. 1.
[3] The Lancet, April 27, 1872.

Mr. Green,[1] of Bristol, has recorded seven cases of syncope from chloroform, of which two died and five recovered. In these latter magneto-faradism was instantly applied on the appearance of danger, one electrode being directed to the neck, and the other over the lower ribs at the left side. The same treatment was used in the two fatal cases, but in the first of them other means were tried first, and some time had elapsed before the current was employed; in the second case, however, it was used at once and failed. In the latter case such extensive fatty degeneration of the heart was discovered, that 'when its action had once ceased, no artificial stimulus could have restored it.' Galvanism (Mr. Green says) will excite muscle to contract, but cannot impart motion to 'rows of fat.' In the five latter cases which recovered, the stoppage of all motion in the heart and lungs was so complete, and the restoration so instantaneous, that no doubt could remain as to the value of the agent employed.

The same surgeon justly lays stress upon the importance of having a faradic apparatus at hand, ready to act immediately when required, as in many cases where death ensued, much time was lost by first using other means, then sending for the apparatus, adjusting and employing it. Seconds or minutes may make all the difference between life and death. Mr. Green, therefore, has for many years not ventured to operate under chloroform, either at the infirmary or in private practice, without having the faradic apparatus ready for instant use; and expresses the opinion that chloroform should never be administered without the same precautions being taken. He believes that in his cases he had caused the faradic current to act directly upon the heart; but it is evident from his description that he acted upon the diaphragm, and thereby caused artificial respiration.

Mr. Prichard,[2] of Bristol, has described the case of 'a courageous and energetic old lady,' who was to undergo removal of the breast for cancer, who took leave of her husband—'a poor feeble-minded old clergyman'—in the dining-room, and walked up to her bedroom for the operation. During the operation, which was more than usually difficult, in consequence of adhesions to the fascia and muscle, she suddenly ceased to breathe, and instantly became quite pulseless. Recourse was had at once to the

[1] Brit. Med. Journ., May 25, 1872.
[2] Ibid., February 22, 1873.

battery,and in a short time she gasped, and afterwards breathed again. Her state appeared to be one of excessive and almost fatal faintness, and the effects of faradisation were marked. The operation was completed, and she did well.

Another case under the care of the same surgeon was that of a man, aged 74, suffering from a large strangulated scrotal hernia. After trying taxis, chloroform was given, and more attempts made to reduce the mass, when attention was suddenly called to the state of the patient, whose pulse had ceased while the house-surgeon had his finger on the wrist, and all respiratory movements stopped at the same time. The old man appeared to be dead for half a minute; but the battery being at hand, the electrodes were applied to his epigastrium and the back of his neck, and he immediately started into life and struggled to sit up. The hernia was reduced.

Two years and a half after this occurrence, he was again admitted with symptoms of acute strangulation. After trying the usual means, it was determined to operate; and the old man fell again into a death-like syncope at the first inhalation of chloroform. He was roused by faradism in the same way, but died three days afterwards of sphacelus of the scrotum and integuments around.

In *Opium-poisoning* the same treatment has done good service. Dr. Lucas,[1] of Brecknock, has used it in the case of a girl aged 11, who had swallowed an ounce and a half of laudanum, sent to her in mistake for a black draught. She soon became very drowsy, and in spite of the use of the stomach-pump, walking about, and sinapisms to the feet and legs, became comatose, so that seven hours after taking the poison she could no longer be roused by shaking or loud speaking; the lower jaw dropped, breathing was stertorous, respiration 6, pulse 100. Faradisation of the upper cervical region, and over the epigastrium, chest, and face, however, now roused her, so that she was able to swallow a grain of Ext. Bellad. dissolved in a teaspoonful of water. This was repeated at intervals, so that she had five applications of faradism, and 16 grains of Ext. Bellad. in four hours, when she appeared out of danger. She made a good recovery. Probably much good was done in this case by the belladonna; but without faradisation the patient could not have been roused to swallow anything. (It is

[1] Medical Times and Gazette, February 25, 1865.

true that the belladonna might have been introduced by the rectum or by the skin.)

Ziemssen recommends to faradise in these cases not only the phrenic nerves, but also the motor nerves of those muscles which act in combination with the diaphragm; that is, the branches which proceed from the cervical plexus to the trapezius, levator scapulæ, and scalenus medius muscles; the nervus thoracicus anterior, which animates the pectoralis major and minor; and the nervus thoracicus posterior and lateralis, which proceed from the brachial plexus to the scalenus medius, serratus anticus, and the rhomboidei. The electrodes should be placed there for about two seconds at the time, in order to produce a deep inspiration; after which expiration is effected by an assistant pressing the abdominal parietes from below upwards. It has been proposed to promote expiration by faradisation of the abdominal muscles, but Ziemssen is not in favour of this proceeding, because he thinks it impossible to produce such a powerful compression of the contents of the abdomen by faradisation as may be effected by mechanical pressure on the parietes, and by pushing the diaphragm upwards. The current should be powerful and rapidly-interrupted. If after the first few times no effect is produced, the intensity of the current must be further increased, as otherwise the excitability of the respiratory nerves might completely vanish.

Onimus and Legros [1] think the continuous current preferable to faradisation. They have experimented on rats, mice, rabbits, and dogs, with ether, chloroform, and nitrous oxide gas; and have found that after respiration had ceased, and the animals had been apparently dead for two or three minutes, a continuous current applied to the digestive tract restored them to life. They recommend to place the cathode into the mouth, and the anode into the rectum, and to apply the current continuatively, until respiration and the heart's action are quite re-established. A current of twenty cells would, according to them, be sufficient for man. Faradisation will, however, in most cases be preferable, because it is easier to use, and when used at once, almost invariably seems to answer.

Dr. Steiner,[2] of Vienna, has recently recommended farado-puncture of the heart in preference to faradisation of the phrenic

[1] Comptes rendus, etc., March 1869.

[2] Langenbeck's Archiv für Chirurgie, vol. xii. p. 741. 1871.

nerve or artificial respiration. He considers the latter means useful for asphyxia, but not for syncope. He undertook experiments to determine whether acupuncture of the heart with a fine needle is dangerous, and found that in horses, asses, dogs, cats, and rabbits, pricking the pericardium and the walls of the ventricles with a fine needle is devoid of danger, and, indeed, hardly perceived by the animal; that if the ventricles are perforated, the prick is also devoid of danger if the needle be left quiet. A fine and non-penetrating injury by a needle leaves hardly any traces on the second day; if it has penetrated, all traces have nearly disappeared by the eighth or tenth day. There is never pericarditis or carditis, unless the parts are irritated by taking firm hold of the needle, or by pushing it about. If the needle perforates the walls of the ventricles, no bleeding occurs as long as it remains *in situ*; when it is withdrawn, drops of blood are squeezed out by each systole for eight or ten seconds; but not during diastole. Pricking the atria is dangerous, as it causes persistent and copious bleeding during systole and diastole. Injury to one of the coronary arteries is likewise dangerous by causing copious hæmorrhage. Taking hold of a needle which is inserted in the ventricle may, if the heart's contractions be powerful, cause a rupture of muscular fibres, which may eventually become dangerous. If the point of a needle which has perforated the ventricular walls is made to touch the opposite inner surface of the heart—which may be recognised by a sort of vibration communicated to the fingers by the needle—the muscular substance may, provided the heart's action be energetic, become so much disintegrated that sudden rupture may take place within a few minutes. There is, however, no place in the heart where the prick by means of a fine needle would at once prove fatal.

The apex of the heart bears injuries best. Dr. Steiner therefore recommends to puncture the apex, which, according to his experiments, is done by introducing the needle in the middle of the fifth intercostal space, about 3 centimètres from the left border of the sternum. By acting in this way, the left pleura, the coronary arteries, and the internal mammary are avoided. The puncture should be made perpendicularly, and should be 3 centimètres deep; in fat persons rather deeper than that. All unnecessary manipulations of the needle, more especially taking hold of it when the heart's action commences, should be carefully avoided.

In those rare cases where electro- (or rather farado-) puncture of the heart has been used, fifteen to twenty minutes had been already wasted by employing artificial respiration and other measures, so that the excitability of the heart was already gone. No cauterising or electrolytic effects need be feared. In animals whose heart was subjected to farado-puncture for fifteen minutes consecutively, no pathological alteration could be observed either soon after, or for some days subsequently to this proceeding. Dr. Steiner believes that where faradisation of the phrenic nerve restored animals from chloroform syncope, this was owing to a portion of the current being 'derived' from the phrenic to the sympathetic or to the pericardial connective tissue, and thinks this the reason why the effects of faradisation of the phrenic nerve should be uncertain. In six of his animals, farado-puncture was successful in rousing the heart's action; in ten, the proceeding failed, but in seven experiments artificial respiration failed likewise.

It would appear that the excitability of the heart is much sooner destroyed in an animal which has been killed by chloroform than in another which has been killed by other means, as by pricking the medulla oblongata. The muscular current of the heart, investigated in Du Bois' manner, disappears within four minutes in the chloroformed animal, while it lasts for ten minutes in one killed by injury. In the muscles of the extremities it lasts for many hours. Sudden paralysis of the heart, which is the cause of chloroform-syncope, is most probably also the cause of fatal asphyxia.

Dr. Steiner concludes from his experiments that farado-puncture of the heart is devoid of danger; that it is no certain remedy for the arrested action of the heart, even if employed at once in chloroform syncope, because the excitability of the heart is rapidly lost under such circumstances; that it is much preferable to artificial respiration, which latter he considers only beneficial when the heart's action is not yet entirely arrested, and which then only acts by the mechanical irritation of the heart produced by the manipulations of artificial respiration. He recommends to connect the needle with the positive electrode, and to put a moistened sponge conductor to the pit of the stomach, or to the left seventh intercostal space. The current should be weak, and only act for a second at a time; thus used, he considers it the best means not only for restoring the heart's action, but also respiration.

The oscillations of the needle which appear, the respiratory movements, the pulse which becomes perceptible, must not induce us to discontinue our efforts before the heart's action has become strong and rhythmical. In this stage artificial respiration, or faradic respiration, might be usefully substituted for farado-puncture of the heart. If fifteen minutes after commencing farado-puncture no result is evident, it is not necessary to persevere, as the heart must then have altogether lost its excitability. Farado-puncture should therefore be performed immediately in all cases of deep unconsciousness with rapidly increasing collapse, when the pulse becomes imperceptible and the face cadaverous. Dr. Steiner's conclusions, in the face of the numerous successes obtained by faradisation of the phrenic nerve, appear to us somewhat dogmatic. We should certainly be inclined to use first the latter proceeding; and only if this should not answer, resort to farado-puncture of the heart.

VII.—HYPERÆSTHESIA.

Hyperæsthesia is due either to primary disease of some part of the nervous system, or to morbid conditions of remote organs which cause an irritation of the nerves; and it depends upon the cause of the hyperæsthesia whether it is amenable to electricity or not. Where the cause cannot be removed by electricity, only symptomatic relief can be afforded by it; while a cure may result where the cause of the hyperæsthesia yields to the electric influence. Thus, for instance, hyperæsthesia may be caused by inflammatory diseases of the uterus, ovaries, and kidneys, or by exostoses in the osseous canals through which the nerves pass in their course to the periphery, &c.; and in such cases we cannot expect electricity to cure the hyperæsthesia altogether, for the irritation of the nerves must continue as long as the disease persists and progresses in those parts; yet even in such cases electricity may produce relief, where medicinal anodynes have been used and failed.

In the milder varieties of hyperæsthesia all the different forms of electricity may be usefully employed, but in the severer forms of it only the continuous current affords relief. Static electricity may be employed in the form of sparks and slight shocks. Faradism may be used by means of the electric hand (p. 416), which is very useful in some forms of headache; or as an *electric moxa*,

one wire-brush being pressed to the skin, while the other is held at a small distance from it, so as to cause sparks to pass from the skin to the wire-brush, or by means of moistened conductors applied to the trunk of the nerve. Whether volta-faradism or magneto-faradism is used in such cases, appears to be indifferent. If the continuous current be used, we must, as a rule, cause anelectrotonus of the suffering nerve by placing the anode, connected with a large sponge, to the suffering nerve, and the negative in the neighbourhood, or at a distance, the application being continuative for from one to five minutes. In obstinate cases of hyperæsthesia which resist other means, galvano-puncture, or rather electrolysis, may be employed, which is the most effective mode of using electricity for the relief of pain.

1. *Neuralgia of the Face* (*tic douloureux*).—There are two kinds of facial neuralgia, a mild one and a severe one. The former generally comes on after exposure to damp and cold, or after mental emotions, or is owing to caries of a tooth; it is not made worse by moving the face, and it occurs at all periods of life; while the latter occurs generally without any apparent cause, is almost entirely confined to advanced age, and is brought on or made worse by the least movement of the face. The former yields to many remedies, and amongst others to the various forms of electricity; while the latter, as a rule, defies every medicinal treatment, and only appears to yield to neurectomy and the constant current. The following case is one of the former kind, and readily yielded to faradisation:—

CASE 47.—A married lady, aged 28, had been in good health until May 1857, when, in consequence of having got wet through, she was seized by violent pain in the right side of the face, accompanied with fever and general indisposition. The latter symptoms soon subsided, but severe shooting pain continued to occur in paroxysms, at the end of which the patient was completely exhausted. For the first few weeks these attacks came on irregularly, about four or five times in the course of the day; but they gradually assumed an intermittent character, only one attack occurring every other day, between four and five o'clock in the afternoon. Large doses of quinine and arsenic had been given, but without producing any effect; the patient had also been treated by calomel, bichloride of mercury, iodide of potassium, and blisters. Her general health had much suffered, and she had become nervous and irritable. She now (October 1857)

always had a warning that an attack was coming on, viz. a kind of tickling in the epigastrium, followed by a sensation of pins and needles in the face. Soon afterwards the pain began to shoot through the zygomatic bone, the lower eyelid, the cheek and chin, was less violent on the nape of the neck, and spared the forehead and temple. Such an attack usually lasted about half an hour, and then slowly subsided into a dull aching pain, which continued for three or four hours. The following day she was free from pain, but on the third day there was another paroxysm. Movements of the face did not increase the pain. On examination of the face, I found two *puncta dolorosa*, viz. on the zygomatic bone, where the temporo-malar, and on the infraorbital foramen, where the infraorbital nerve emerges from the orbit: these two points were decidedly tender on pressure in the free interval. I used faradisation, directing the electrodes alternately to these two points, by means of moistened conductors, conveying a rapidly-interrupted current to the suffering nerves. The first application made at the time when the attack had just commenced relieved the severity of the pain, but did not shorten the duration of the paroxysm. Two days after, another attack came on in due time, but was then much shortened by faradisation. On the third day after that, there were premonitory symptoms, as usual, but no attack. Next time a paroxysm came on which was subdued in five minutes. Faradisation was used five times more, after which the patient appeared to be free from the disease. I saw her again in the beginning of June 1858, when she told me that up to that time she had been perfectly well.

Cases of that severe form of facial neuralgia which Trousseau has appropriately termed *epileptiform neuralgia*, and which is also called *Fothergill's disease*, resist the influence of faradisation. They yield for a time to excision of a piece of the suffering nerve, but are apt to return as soon as regeneration of the nerve has taken place; and even before that the neuralgia often invades neighbouring branches of the trifacial, so that further surgical operations become necessary. I believe that in this affection the constant current is preferable to neurectomy; in the first instance because it does not injure or destroy the nerves which are necessary for the proper nutrition of the face; and secondly, because it has the power of completely altering the nutrition of the affected nerves, owing to which it appears to produce more permanent effects than neurectomy. The most important case of

epileptiform neuralgia which has up to the present time been placed on record, is one which occurred some time ago in the practice of Professor Niemeyer, of Tübingen, and which has been described by Dr. Wiesner.[1] In this case surgery and electricity had both a fair trial.

The patient was a huntsman, aged 64, accustomed to live in the open air and to 'rough it.' Five years before he came under Prof. Niemeyer's care, he first felt a 'painless shock' through the left side of the head and face; and such shocks returned at frequent intervals. After this had gone on for a twelvemonth, attacks of severe pain came on, which commenced at the angle of the left jaw, and proceeded through the zygomatic arch right into the skull. Such attacks occurred at first about once in three weeks, and were generally owing to some exciting cause, such as smoking, masticating, speaking, wiping the mouth, &c. Pressure neither increased nor diminished the pain, the fits of which gradually became more frequent. The shocks lasted only one or two seconds, but recurred twenty or thirty times in the course of the day in the third year of the disease. In 1864 the patient consulted Prof. Billroth, of Zurich, with the view of undergoing a surgical operation. The pain at that time never came on without touching or moving the left side of the face, nor did it occur during sleep; it affected the left cheek, the upper lip, the upper jaw, and the teeth. A few decayed teeth were extracted, but this gave no relief whatever. A number of remedies, such as quinine, iron, arsenic, iodine, and veratrine, were then given, with the same result; and only subcutaneous injections of morphine produced temporary benefit. By the advice of the late Prof. Griesinger, four leeches were put to the diseased side; and this was repeated a week after, but the condition of the patient remained exactly the same. Prof. Billroth then excised a piece of the infraorbital nerve, one and a quarter inch long, from the infraorbital canal. The piece of the nerve which had been excised was carefully examined with the microscope, but was found to be perfectly healthy. The patient only remained free from pain for a few days, after which the attacks reappeared, although not quite so frequently nor so severely. At that time the attacks were brought on by pressure on the left upper jaw; and the parts animated by the infraorbital nerve remained free from pain. The paroxysms, however, getting continually worse, Prof. Griesinger advised the removal of the

[1] Berliner klin. Wochenschrift, No. 17, 1868.

painful parts of the alveolar process of the jaw by means of raspatories. The patient was not put under the influence of chloroform for this operation, as he had to state which parts of the bone were tender. The operation was excessively painful, but had a favourable result; the patient was discharged on May 27, 1864, being then apparently quite well.

He came back in February 1866, and reported that for some time he had been quite easy, but that the attacks soon returned, and gradually became more frequent and severe. He urgently demanded a 'radical operation.' The left cheek was now free from pain, but all the other parts which are animated by the second branch of the fifth nerve were affected. Prof. Billroth then performed osteo-plastic resection of the upper jaw, as proposed by Von Langenbeck. He broke off the posterior wall of the antrum, and the posterior part of the lower portion of the orbit, dissected away the second branch of the fifth nerve up to the foramen ovale, and divided the nerve close to the foramen rotundum. The zygomatic and superior alveolar branches were then drawn out as far as possible, and likewise removed, and the infraorbital nerve was entirely taken away. The operation was not followed by any bad symptoms, and the wound of the jaw healed well together. A careful microscopic examination of the excised piece of the nerve again showed no alteration whatever.

This operation did good for a time, but towards the end of March of the same year fresh paroxysms of pain occurred on touching the left upper lip. They soon became so severe, that Prof. Billroth excised on April 6, 1866, the buccinatorius nerve which branches off from the third ramus of the fifth. This operation was rendered difficult by the numerous cicatrices consequent upon previous operations; the ductus Stenonianus was injured close to its point of exit from the gland, and erysipelas set in afterwards, but yielded to treatment. The pain was now quite gone, but a salivary fistula remained. In May the tic was again as bad as ever in the left side of the palate and the chin. On May 9, therefore, Prof. Billroth cut away from the cavum oris through the lateral wall of the antrum, in order to excise the posterior dental nerves, and resected at the same time the mental nerve at its exit from the inframaxillary canal. On May 21 the salivary fistula was operated for, the anterior portion of the gland being removed, and the skin united by sutures. The parts did not heal, but suppuration set in, and the whole gland gradually

sloughed away. In July 1866 the patient left the hospital free from pain, and also cured of the fistula.

He did not, however, long continue in good condition. In December 1866 the attacks were again very frequent. He was readmitted in July 1867, when the pain was excessively severe; it then proceeded from the dental process of the upper jaw, and radiated towards the nose, the lower eyelid, ear, and temple, from where it penetrated into the cavity of the skull. Prof. Billroth then advised the use of the constant current; but as the patient believed that he could only be cured by a surgical operation, the Professor, on the urgent entreaties of the poor man to do something for him, tied the left common carotid artery, just below the omohyoid muscle. During the first few days after this operation, a few feeble shoots of pain came on, but they soon ceased, and on the seventeenth day the patient left the hospital apparently well. But again the improvement was only temporary, and as Prof. Billroth had, in the meantime, left Zurich for Vienna, the patient went to Tübingen to consult Prof. Niemeyer concerning the applicability of galvanism.

He was admitted into the hospital in December 1867. At that time he used every day eight grains of morphia for subcutaneous injections, this being divided into three doses. Fits of pain came on twenty or thirty times during the day; their starting-point being the maxillary articulation, whence they spread to the anterior side of the ear, and the left parietal bone. They came on chiefly on touching the left upper lip. The constant current was now used, and with such beneficial effect, that the patient was soon enabled to discontinue the subcutaneous injection of morphine. After three months' treatment, the current having been applied nearly every day, the patient left the hospital apparently cured. Whether the effect of the galvanism will be more permanent than that of the surgical operations, remains to be seen; but if a relapse should occur, the same remedy would probably again produce the same effect. The current was applied, by moistened electrodes, to the affected nerves, no regard being had to the direction of the current, and for five minutes at a time; sometimes both electrodes were directed to the skin, at other times one was directed to the skin and the other to the mucous membrane of the mouth.

Dr. Wiesner has recorded another case of a similar kind which occurred in a patient, aged 74 at the time he came under treat-

ment, when he had already been a sufferer from the neuralgia for twenty-nine years. In this case a host of external and internal remedies had been used without effect; M. Nélaton had refused to perform an operation, and so had Prof. Bruns, of Tübingen. The induced current had been used as 'electric moxa,' but without producing any benefit. In July 1867, Prof. Niemeyer used the constant current, connecting the positive pole with a moistened conductor, and the negative with a wire-brush. After twenty such applications, the pain was gone, and only a slight increase of sensibility remained in the upper lip. Some months afterwards there was a relapse; but this yielded rapidly to galvanisation.

Cases of long standing, and occurring in old people, are generally difficult to cure, and require a prolonged treatment. Tic douloureux would probably cease to be looked upon as incurable if the trifacial were placed under the influence of anelectrotonus soon after the commencement of the affection.

CASE 48.—A merchant, aged 64, widower, living in a manufacturing district, had for eight years suffered from epileptiform neuralgia in the right side of the face, which had first come on after a fatiguing journey undertaken in winter, and under anxious circumstances. Since then the neuralgia left him only occasionally; and when he came under my care in January 1869, he was not free from attacks a single day. Fits of pain came on after the slightest movements of the lips, chiefly during mastication, and in speaking, stooping, gaping, coughing, and sneezing. An intercurrent attack of dyspepsia, to which he was rather subject, always increased the severity of his sufferings. He was generally free from pain at night. The severity of the suffering was such as to drive him nearly mad; and he had not known any enjoyment of life during the last eight years. When an attack came on, he could not help calling out or screaming, and he had not been to church for a long time, because he had sometimes been obliged to call out in the middle of the service. His general health was tolerably good, except that there was atheromatous degeneration of the valves of the heart, which gave rise to occasional bad attacks of dyspnœa. No puncta dolorosa could be found in the course of the trifacial nerve, the only objective symptom being a swelling in the mucous membrane of the right cheek, which was the principal seat of the pain. Digestion was good, but the patient was obliged to take his food minced very fine,

because otherwise the act of taking it hurt him 'awfully.' He was also obliged to avoid anything hot, as this caused severe pain. No part of the right side of the face was quite free from the neuralgia, but the worst points were the temple and the cheek. It is unnecessary to mention the various remedies which had been used for the relief of the pain, as nothing seemed to have had the slightest beneficial effect. I now used the constant current, applying at first the positive pole externally to the cheek and the temple, and the negative to the superior cervical ganglion; but as this application produced no perceptible effect, I introduced the next day an insulated metallic sound connected with the negative pole into the mouth, and touched with it the painful swelling in the mucous membrane of the cheek, the anode being alternately placed to the temple and the external surface of the cheek, altogether for five minutes. A current of ten cells was used. Immediately after the application was over, the patient exclaimed: 'That has done good!' The next morning he was in high spirits, as he had been quite free from pain during the remainder of the day, and had been able to masticate and eat his dinner without any trouble. He had had a good night, and it was only at breakfast that the pain had to some extent returned, although not nearly as bad as before. Within the next few days the patient had a bad attack of diarrhœa; nevertheless the pain remained in abeyance on masticating as well as on stooping. After the current had been applied a few more times, the inside of the cheek had become rather sore, and the treatment was therefore discontinued for a few days. The diarrhœa did not yield to the remedies used for it, and the patient consequently got very much below par; under these circumstances, about a fortnight after the commencement of the treatment, the pain returned much in the same manner as before. The patient then had another internal application, after which he was again much better. The next day, however, he was seized by a bad attack of influenza, and the pain returned. When he had recovered from the influenza, he went to the seaside for change of air, and the neuralgia has since then continued in nearly the same manner as before. In this case galvanism was certainly used 'under difficulties;' as the patient had, during the time he was under the influence of it, two acute affections which interfered considerably with his general health; and I consider it highly probable that, if the galvanic treatment could have been continued for some time longer, and under more favourable circumstances, a cure would have been effected.

Dr. Wilks[1] has recorded a case where the first division of the fifth nerve was involved on the left side. The patient, while in Guy's Hospital, took aconite, chloride of ammonium, hydrated peroxide of iron, quinine, and bromide of potassium. None of these drugs did any good, and the continuous current was then used. She was better in a few days, and in a month's time had quite recovered.

Dr. Anstie's theory of atrophy of the posterior nerve-root being the cause of neuralgia, is probably correct for a large number of cases; and if we have reason to suspect this pathological condition, the production of catelectrotonus would appear preferable to that of anelectrotonus.

In this as in most other cases, however, we must be guided by the results of the first few applications. My own experience would always induce me to commence with anelectrotonus; but I have seen this fail in sufficiently numerous instances to induce me not to attach undue value to its production. If therefore anelectrotonus does not answer quickly, we should induce catelectrotonus, or embrace the nerve between the positive and negative current, the anode being put to the skin, and the cathode to the mucous membrane.

2. *Headaches.*—There are few headaches which resist faradisation by the electric hand, or a gentle continuous current; but we must always enquire into any derangements of the stomach or other organs which may be present, and which are so frequently instrumental in producing headaches. Yet many cases occur where a judicious medicinal treatment fails in relieving the headache, and where this is promptly cured by electricity. I have seen a large number of such cases, in which either of the above-mentioned methods of applying galvanism proved successful.

A frequent and peculiar form of headache is the *sick headache* (hemicrania). This generally resists faradisation, but yields to a persevering use of the constant current, applied through the mastoid processes and the temples. In cases where guarana or coffeine do no good, galvanisation should therefore be resorted to without delay.

3. *Photophobia.*—This troublesome symptom frequently accompanies diseases of the cornea and conjunctiva, and obliges the patients to keep their eyes closed. It often resists medicinal

[1] Brit. Med. Journ., 1872, p. 435.

treatment, and generally yields to the constant current. Mr. Hewson has placed on record thirty-two cases of photophobia due to strumous inflammation of the cornea in children, which were all cured by the application of the continuous current. These children were between one and six years of age. The induced current made them worse, while from one to three applications of the continuous current relieved the affection. He placed the cathode to the supra-orbital foramen, and the anode to some part of the face. Other observers have obtained equally beneficial results.

CASE 49.—A married lady, aged 37, had suffered from glaucomatous inflammation of the left eye in the autumn of 1865. The cause of the affection was believed to have been rheumatic. She was seen by many oculists and physicians, and underwent iridectomy, but without much benefit. When I first saw her, in May 1868, I found her highly hysterical; she suffered from convulsive attacks, dizziness, palpitations of the heart, and pain in the epigastrium, back, and side. The most troublesome symptom, however, was intense photophobia, so that she would not leave her room, which had always to be kept dark. She was with some difficulty persuaded to have a gentle constant current applied to the eye. The anode was placed on the closed eyelid and the cathode to the superior cervical ganglion. She felt much better after the first application, and after three more the photophobia was gone.

4. *Tinnitus aurium—noises in the head.*—The pathology of this troublesome symptom consists at present, according to Mr. Hinton, of a few scraps of positive knowledge, with a great deal of conjecture. It generally appears as age advances, and is probably due to impaired nutrition of the fifth or the auditory nerve. It sometimes yields to galvanisation, even when it has existed for many years. The current should be applied to the membrana tympani, the cervical sympathetic, and through the mastoid processes, intermittently, with voltaic alternatives.

5. *Cervico-occipital Neuralgia.*—This occurs in the sphere of the occipital nerves, which arise from the upper four cervical nerves, and has the same pathology as tic. It is curable by galvanisation, but great care is necessary in using the current, as it may do harm if the application is too long or too strong, or if the treatment is too long continued.

CASE 50.—A lady, aged 49, had suffered from cervico-occipital

neuralgia for the last twenty years when she came under my care (July 1869). No medicine had ever done her the least good, and the only thing which had for a time removed the pain was the actual cautery, which was applied by Sir James Paget in 1868. The pain, however, returned some time afterwards, and was now as bad as ever. The least touch 'drove her nearly wild,' and it was an 'agony' to have her hair dressed. I applied the constant current to the occipital nerves continuatively for two minutes, with the effect that the pain was nearly gone after the application; 'it seemed to have hardened her head;' she had a comfortable day and night, and the hair was dressed the following morning without inconvenience. The current was now used several times more; but after the third application there was a considerable increase in the severity of the pain, together with restlessness, sleeplessness, and general nervous disturbance. The treatment was therefore given up. This case would probably have done better if only one or two applications had been made; and I now make it a rule not to apply the current again when the pain has completely disappeared. In such cases the neuralgia may be owing to a faulty (peripolar or dipolar) arrangement of the electrical molecules of the nerve, which may be set right by one or two applications of the constant current, but may be again disturbed by further applications, more especially in persons of such highly sensitive constitution as the patient whose case has just been described.

The following is a case of brachial neuralgia:—

CASE 51.—A married lady, aged 32, was sent to me by Mr. Wolff, of Gower Street, in July 1871. She had for the last three or four years suffered from severe neuralgia in the right arm and shoulder, with this peculiarity, that she never was actually free from pain, but suffered constantly, at times, however, much more than at others. There was slight thickening in the supra-clavicular region, but otherwise no structural change could be made out anywhere. The arm was almost useless to the patient, as she found that the pain became much worse when she attempted to do anything with it, so that she dreaded using it at all. Her general health was otherwise tolerably good, and no particular cause could be assigned for the occurrence of the neuralgia. She had used a considerable variety of remedial measures, but all to no purpose, and the pain was getting worse instead of better. I now applied the continuous galvanic current to the sympathetic nerve, and to the thickening in the supra-

clavicular region. Three applications produced apparently no effect, but after the fourth she was better, and after the fifth a good deal better. After a fortnight's treatment, the pain was entirely gone. Two years later, I had the satisfaction of ascertaining that the patient had continued perfectly well ever since.

Cases of *pain in the back* and of *inframammary pain* are generally curable by electricity. Inframammary pain is in some instances dependent upon incipient lateral curvature of the spine, but more frequently exists without any apparent structural lesion. It is generally felt below the left mamma and at the margin of the ribs. I have seen a number of cases of this affection, some associated with amenorrhœa, others not. In those patients who suffered from amenorrhœa, the return of the catamenia and the disappearance of the pain were simultaneous.

Intercostal neuralgia often yields to galvanisation or faradisation.

In the neuralgic stomach-ache (gastrodynia), which is owing to a functional derangement of the solar plexus of nerves, and where the pain is frequently confined to a small place on a level with the central ganglion, the continuous current is one of the most useful remedies at our disposal. The effect is, in most cases, immediate, and if the treatment be persevered in for some time, permanent.

In *sciatica*, faradisation as well as galvanisation frequently prove successful. It is sometimes advisable to combine them with subcutaneous injections of morphia and atropia.

CASE 52.—A Scotch farmer, aged 35, came under my care in July 1857. He had never been in strong health, and suffered for a long time from excessive acidity in the stomach. Eight years ago he had his left thigh amputated for tumor albus, and he wears now an artificial leg, which, being very heavy, exerts a great strain upon the left side of the pelvis. Three years ago, he first began to feel pain on the back of the right thigh, and the inside of the leg, down to the ankle. This was at first dull and heavy, but after a time became so acute that he was laid up with it. He thought it was brought on by his having taken too much exercise. He did not suffer from violent attacks of pain followed by free intervals, but had no rest whatever. He placed himself under the care of two eminent practitioners in Edinburgh, and after some time was much relieved, the acuteness of the pain slowly but gradually subsiding. He then left Edinburgh; but being still very bad, had acupuncture applied, from which he

received immediate relief, but the pain never entirely left him, and was much about the same shortly after the operation. About two years afterwards he came to town and consulted Sir James Clark, who sent him to me. The pain was 'a dull ache' at that time; it increased on walking, even for a short distance, and in the first part of the night. Pressure had no marked influence upon the pain; but it rather relieved than increased it. The muscles of the leg twitched a good deal in the morning, but not much in the course of the day; these twitches were painless, and no doubt due to mal-nutrition of the limb. I used faradisation of the skin, by wire-brushes, but as two such applications produced no effect, I applied the next day moistened electrodes, placing the positive one to the tuberosity of the ischium, and the negative to the ankle for six minutes. Immediately after this application the pain was gone; it returned three hours afterwards, but was not nearly so severe as it had been before, and the patient had a good night's rest. I faradised the nerve three times more; after the second application, the pain went away till the following morning; and, after the fourth, it was only slightly felt in walking, but not when at rest. The patient was then obliged to leave town. Six weeks afterwards I received a note from him stating, that since faradisation was used, the limb had been a good deal better. He was, however, not totally free from pain when he walked to any distance; yet the pain went off sooner, was less severe, and not so liable to return as formerly. I therefore advised him to undergo another course of the same treatment. This the patient did some time afterwards. Faradisation was used six times more as above, and with such beneficial effects that he could walk three or four miles at a time with perfect ease.

Benedict has recommended for certain forms of sciatica, in which the percutaneous application of the current does not answer, to introduce one direct or into the rectum, and put the other to the sacro-lumbar region. The current reaches the nerve more thoroughly when applied in this manner. Where the pain is constant, the local application to the nerve is the best; but where there are instantaneous lancinating pains, the spinal cord should likewise be acted upon.

The following is a case of diffuse neuralgia, which was remarkable for its cause and rapid cure:—

CASE 53.—A merchant, aged 30, of vigorous constitution, and

active habits, was a passenger by the Canadian steamer which foundered at sea on the 4th of June, 1861, about 200 miles off the coast of Canada. Many of the passengers were drowned; but this gentleman, by means of a life-buoy, was enabled to float until, three-quarters of an hour afterwards, he was picked up by a boat which was passing. Life was then almost extinct. The water was at the time excessively cold, as large masses of ice were floating in it. The patient soon rallied, but had unfortunately to remain in his wet clothes for a long time; and, even after he had landed, he could not at once obtain a change of dress. He did not at first experience any bad effects from this accident; but, after some time, began to feel severe burning pain in the arms and legs, followed by numbness in the limbs and loss of muscular power. He soon afterwards returned to England, and was, during his passage, subjected to treatment by the ship-surgeon, who prescribed applications of opium and aconite to the arms, and general tonics; but he derived no benefit from the remedies used. On his arrival in this country he consulted Mr. Snape, of Bolton-le-Moors, in Lancashire, who thought that faradisation would be the best means of restoring him, and sent him to me. On examination, I found the following morbid symptoms:—There was a burning neuralgic pain, especially in the fore-arms and thighs, which increased very much towards evening and in the night; so that the patient was prevented from sleeping, and in consequence became much exhausted in the morning. There was also anæsthesia, especially in the right hand and fore-arm, where the prick of a pin could not be felt; while in other parts, sensation was very blunt. The sense of touch, especially in the right hand, was much diminished. Finally, there was a semi-paralytic condition of the arms; the patient could move them, but he had no power over the muscles; he could not grasp anything with force, and experienced great difficulty in writing. The contractility of the muscles was not diminished, as they answered readily to a faradic current of moderate power, only the influence of volition over them had considerably decreased. The flexor muscles of the fore-arm were most affected. The general health of the patient was good, notwithstanding the loss of rest, and the wear and tear consequent upon great suffering. I faradised the skin and the suffering muscles, with excellent results. The pain, which was severe at the time the patient came to me, disappeared during the first

application; and he slept soundly the following night. The pain returned in the morning, although in a less degree; and, after a few more applications, it was entirely subdued. The anæsthesia also yielded rapidly to the means employed. After three operations, the patient was again able to feel distinctly not only the prick of a pin wherever I applied it, but also the mere touch of blunt instruments; and when he left town, after having been under my care for six days, he was free from pain, the anæsthesia was gone, the sense of touch was normal, and the muscular power had returned. I have not seen him since; but Mr. Snape has written to me to say that the effects of the treatment have been permanent; and that the patient returned to Canada some time afterwards in perfect health.

There are two other painful conditions, in which the constant current finds a useful sphere of action, viz. cancer and ataxy; but as both these complaints will be considered under separate headings, we shall defer the remarks we have to make on this subject.

VIII.—SLEEPLESSNESS.

In many forms of nervous complaints, sleeplessness is a prominent and important symptom; and where it does not yield to the ordinary medicinal remedies, anelectrotonus of the spinal cord and brain should be produced, which is often instrumental in restoring sleep where chloral and other soporifics have already had a fair trial. The application should be gentle, and last from five to ten minutes.

IX.—PROGRESSIVE LOCOMOTOR ATAXY.

The first stage of this disease is characterised by hyperæmia of the blood-vessels and effusions in the neuroglia of the posterior columns of the spinal cord, and lasts generally one or two years. Its principal symptoms are alterations of the pupil, paralysis of certain ocular muscles, and shooting pains in the limbs combined with anæsthesia. In the second stage there is considerable proliferation of connective tissue, together with wasting of the nervous matter. Peculiar alterations in the gait, and loss of power in the bladder and sexual organs, make their appearance. The third stage is characterised by intensification of the pathological lesions and paralysis.

Precious time is often lost in the first stage of ataxy with employing medicines, mineral waters, &c., while galvanisation should be resorted to at once. No other remedy produces equally prompt effects as the constant current in this disease, more especially when it has not yet far advanced. But even where the second or third stage has been reached, the current relieves many symptoms, and does more good than any other treatment. Catelectrotonus of the spinal cord should be produced daily for five minutes, and may be combined with local applications, where local symptoms demand interference. Our own experience in this matter entirely agrees with that of Benedict,[1] Onimus,[2] Krafft-Ebing,[3] and Dr. Wilks.[4]

The *pain of ataxy* demands special consideration. There are indeed few kinds of pain which equal, and none which surpass in severity, the pain which accompanies certain forms and stages of progressive locomotor ataxy. This pain is short, sharp, and sudden; there is an instant or two of indescribable agony, followed by twenty or thirty seconds, not of rest, but of a kind of drowsy stupor, out of which the patient is roused by another pang, similar to, or even worse than, the first. I have known strong men, who could bear a great deal without flinching, scream under this infliction; and frequently their cries could be heard at a distance. The pain generally reaches its acme of severity on the third day from the commencement of the attack, and remains of the same character until the eighth day, after which there is a kind of lull. The patient, although utterly wearied and exhausted by suffering and sleeplessness, is, as it were, able to breathe again, as the shocks become less frequent and less severe. Sometimes the pain is quite gone by the tenth day; at other times it goes on in a subdued and sullen manner until a month has passed since its commencement.

Most usually the seat of pain is in the feet and knees, rarely in the hips and back, and quite exceptionally in the upper extremities and the head. Neither swelling nor redness is perceptible during these attacks, which are often set down as being such of suppressed gout. They occur, however, in persons who have no gouty habit at all, and do not yield to the remedies which prove most useful in the gouty diathesis. Indeed, the peculiar obsti-

[1] Loc. cit.
[2] Gazette des Hôpitaux, No. 116. 1868.
[3] Deutsches Archiv, etc., 1872, vol. ix. p. 274.
[4] Brit. Med. Journal, January 1873.

nacy with which the atactic pain defies purely medicinal treatment—even a bold use of hypodermic injections being generally futile—constitutes one of its chief characteristics. That the pain is really part and parcel of ataxy is proved by the concurrence of other symptoms which the patient often omits to mention on giving an account of his case, but some of which can be invariably elicited by inquiry. Thus we find that some time previously there has been transitory double vision, or other affections of cerebral nerves; that there are sexual debility, and weakness and unsteadiness in walking.

It appears probable that the paroxysmal pains of ataxy are owing to tetanic spasms of the muscular coats of the arteries, caused by irritation of the vaso-motor system of nerves. We have, therefore, to look for remedies chiefly amongst those agents which we know to possess a powerful influence on the sympathetic. Amongst these the continuous galvanic current stands *facile princeps*; and I will now shortly relate a case in which it brought relief, which had for years obstinately resisted all other medication.

CASE 54.—J. B., a merchant, aged 35, married, came under my care in February 1870. He had for the last six years suffered from periodical attacks of severe pain in some part of the lower extremities, principally the right foot and the left knee. Such an attack generally lasted from two to four weeks, after which the patient was free from it for two or three months, at the expiration of which time a fresh attack would come on. He had never had syphilis. Early in 1864 he suffered from double vision, owing to paralysis of the rectus externus of the right eye. This yielded to treatment in about six weeks, and since then his eyes had been weak, although not suffering from any definite disease. Soon afterwards he noticed that his sexual power was diminished, and that he occasionally had nocturnal emissions, which had not occurred during the previous period of his married life (four years). In August 1864 he had the first attack of pain, which was treated with blue pill, opiates, belladonna, and quinine. It lasted about a month, and then vanished. A second attack came in December of the same year, and was treated with colchicum and alkalies. It lasted nearly the same time as the first. When he recovered from the second attack, he felt very weak on his legs, and he had never since then been quite steady, his gait being staggering, chiefly in the dark. Attacks now occurred with considerable

regularity every two or three months. Some of the later attacks were treated with hypodermic injections of morphia, but with little or no effect. It is true that for fifteen or twenty minutes after the injection the pain was generally not quite so severe as before, but it rapidly resumed its ordinary type. The patient had also tried a great many different kinds of baths; in fact, as he expressed himself, 'everything except galvanism,' when he came under my care.

He was in bed when I first saw him, racked with pain, which shot periodically through the right instep. I persuaded him, much against his will, to let me use the hypodermic syringe, and injected one-third of a grain of morphia with one-thirty-sixth part of a grain of atropia, near the internal malleolus. This had no further effect than to make him feel somewhat giddy, and to make the tongue very dry; but it did not relieve the pain at all. The patient being convinced of the uselessness of this proceeding in his case, at my next visit I used at his urgent request the continuous current. This was applied, not *loco dolenti*, but at the neck, to the course of the cervical sympathetic nerve. After the first application the patient had about an hour's freedom from pain; after the second, a somewhat longer interval took place; and after the third, the severity of the suffering was considerably diminished. He had altogether ten applications in eight days, after which the pain was entirely relieved; while usually such an attack had lasted a month with him. I now put the patient on a course of nitrate of silver—almost the only medicine which he had not yet taken—for improving the other symptoms of ataxy; and he took this, in doses of from one-sixth to a half grain, for six weeks, with decidedly good effects. He continued quite free from pain for about six months, the next attack occurring in August, having been due in May or June. This attack was not nearly so violent as that in February, and yielded to galvanisation of the sympathetic in the most satisfactory manner. Until April 1871, when I last saw him, no further attack had taken place; and although it would be rash to assume that the patient will remain altogether free, yet life has in the meantime been rather an enjoyment to him than a burden, and his prospects altogether appear decidedly favourable.

X.—SPINAL EXHAUSTION.

Atony of the spinal cord not unfrequently occurs without any structural disease, and is often not recognised, because many practitioners look upon the complaints of these patients as the mere offspring of a disordered imagination, and therefore class them under the convenient name of hypochondriasis, in the male sex; and of hysteria, if occurring in women. The illness of such patients, however, is not imaginary, but real, and they suffer quite as much as if they were affected by some organic disease. One form of spinal exhaustion is characterised by nervousness, imperfect digestion, and increased elimination of urea by the urine. Of this form, which I have reason to believe to be very frequent, the following is a good example:—

CASE 55.—F. S., aged 42, a gentleman actively engaged in speculative business, had to do unusually hard work, and to undergo considerable anxiety during the autumn of 1865. He had felt nervous and irritable for a long time previous to this; but the first symptom of real illness which supervened was sleeplessness, which commenced in November 1865, and gradually got worse until March 1866. He either did not go to sleep at all on getting into bed, or if he dropped asleep from utter weariness, he woke up again in about half an hour, and lay restless during the remainder of the night. Besides this, he complained of a feeling of great exhaustion, total disinclination to work, and to bodily exercise of any kind; of weakness in the back, and pain at the nape of the neck. He was easily excited and worried by little things, and extremely intolerant of noise, or of being asked any questions. He was often troubled with a sense of vague alarm, and distressing sensations in the head. He disliked his meals, and generally suffered from heaviness on the chest, flatulence and pyrosis, which seemed to be independent upon the quality or quantity of the food taken, and which came on chiefly after emotions or excitement. He was also much inconvenienced by frequent calls to pass the urine, especially in the morning after breakfast. The analysis of the urine showed at once the nature of the morbid condition, as I found it to contain a considerable excess of urea. I now examined the urine daily for some time, and found that this excess of urea was not accidental but constant. The body-weight of the patient was eleven stone three pounds, and the

daily quantity of urea excreted by him should therefore have been about 550 grains. It was, however, continually several hundred grains in excess of this, as shown in the following table :—

Date.	Number of Fluid Ounces of Urine passed in 24 Hours	Specific Gravity of Urine	Quantity of Urea in Grains	Morbid Excess of Urea in Grains	Treatment
March					
17	58	1027	808	258	
18	not noted	not noted	not noted	not noted	
19	,,	,,	,,	,,	
20	56	1027	780	230	Galvanism
21	52	1027	724	174	
22	57½	1027	801	251	Galvanism
23	46	1026	638	88	
24	52	1026	721	171	
25	not noted	not noted	not noted	not noted	
26	57	1026	790	240	Galvanism
27	52	1025	718	168	
28	48	1025	662	112	Galvanism
29	47	1025	649	99	
30	49	1024	671	121	
31	44	1024	603	53	Galvanism
April					
1	not noted	not noted	not noted	not noted	
2	,,	,,	,,	,,	Galvanism
3	42	1023	557	7	
4	46	1023	611	61	Galvanism
5	43	1022	554	4	

This patient was only treated with the application of the constant current to the spine; and the influence of each application in diminishing the excretion of urea is well shown in the table. The improvement in the general health went *pari passu* with this. The patient had three hours' uninterrupted sleep after the first induction of anelectrotonus, and that most troublesome symptom, sleeplessness, which had resisted morphine, was soon entirely removed. After three weeks' treatment the patient felt like another man, being able to exert himself both mentally and bodily, to enjoy his meals, and to take an interest in the concerns of daily life.

The case just related, to which I might add many more, shows in a striking manner how much the functions of digestion and urinary secretion are under the influence of the nervous system.

Patients of this class have no disease of the stomach or the kidneys, as they are often inclined to believe, but suffer from impaired nutrition of the cord, which is a functional disorder, and generally yields to galvanisation. No doubt patients of this class are often benefited by rest, change of air, mineral acids, arsenic, nitrate of silver, and other nerve-tonics; yet in almost all those whom I have had under my care, some such remedies had already been employed without much or any result; and I am satisfied that none of them equal the constant current in efficacy and quickness of effect. If applied in the manner described above, the current has no direct effect on the stomach, and yet it cures dyspepsia; it has no immediate action on the kidneys, and yet it checks the morbidly-increased elimination of urea; it has, however, a powerful influence on the condition of the ganglion-cells of the spinal cord, and on the current of animal electricity in it. In strengthening this current, where it is weak; in correcting it where its direction may be perverted, it not only does away with the weakness and morbid excitability more immediately depending upon the pathological condition of the cord, but it also indirectly removes symptoms on the part of remote organs, such as the stomach and kidneys, which are due, not to a disease of their own structure, but to a perverted and diminished nervous supply, which prevents them from properly fulfilling their functions in the human economy.

Spinal exhaustion likewise occurs in young persons who have grown unusually fast, and is then often associated with increased elimination of phosphates by the urine.

Case 56.—A young lady, aged 22, very tall and of sallow complexion, came under my care in February 1866. She had grown rapidly, especially between her seventeenth and nineteenth year, and had been ailing ever since. All the symptoms were referable to imperfect nutrition of the spinal cord and osseous system, and had lately increased to such an extent as to cause her parents much uneasiness. Being of an impulsive and highly-gifted nature, she would take a passionate interest in certain things, and devote many hours of hard work to mastering a subject which attracted her imagination; after which she would be completely exhausted and prostrated for days or weeks, and be unable to do anything whatever. She often suffered from excruciating pains in the lower part of the spine, especially on making a sudden movement. She was almost entirely incapacitated from

taking active exercise, partly by pain and partly by weakness. The bones were sore and tender, and there was an excess of phosphates in the urine. Her appetite was fanciful, her digestion weak, and the bowels habitually costive. The catamenia were regular, but pale and scanty. She had already taken a great many medicines, amongst which was phosphoric acid in combination with iron. I prescribed phosphorus in the form of the hypophosphite of lime, and applied the continuous current to the cord and the root of the spinal nerves three times a week for a month. The patient was, in about a fortnight from the commencement of the treatment, able to walk out and take active exercise. Her digestion gradually improved, the morbidly-increased elimination of phosphates by the urine was checked, the catamenia became of a healthy character, and the bones became less sensitive. She took the hypophosphite altogether for three months, after which she appeared quite well. She had become stouter, and could walk for miles without fatigue. The beneficial effects of galvanisation were very strikingly shown, inasmuch as at first the patient could only walk on those days when the current had been applied, but not on the other days. The pain which she used to feel in the spine disappeared after two applications of the current—a circumstance which could not be ascribed to the medicine she was taking, as this has a very slow and gradual action in the system, while the effect of galvanisation is generally immediate.

XI.—EXOPHTHALMIC GOÎTRE, BASEDOW'S DISEASE, GRAVES'S DISEASE.

This disease occurs chiefly in female patients between twenty and thirty years of age, and its principal symptoms are palpitations of the heart, enlargement of the thyroid body, and exophthalmus. A purely medicinal treatment rarely does much good, and the proceeding known as galvanisation of the cervical sympathetic nerve appears to be the most rational remedy for it. Dr. Wietfeld [1] and Moritz Meyer [2] have used it successfully in several cases, and as most internal remedies do no good in Basedow's disease, this should in its very commencement be treated by the constant current.

[1] Medical Times and Gazette, November 1868.

[2] Berliner klinische Wochenschrift, No. 39. 1872.

XII.—PROGRESSIVE MUSCULAR ATROPHY, WASTING PALSY, CRUVEILHIER'S DISEASE.

The pathology of this affection is still unsettled, for while some physicians believe it to be a primary disease of the muscular substance, others look for its seat in the grey matter of the antero-lateral columns of the cord. I hold the latter opinion, and therefore strongly advise to treat the complaint from the first by galvanisation of the cord and the cervical sympathetic nerve.

There are two forms of this disease, the *partial* and the *general* form. The general form begins either in the upper or in the lower extremities, and, as it almost always spreads to the trunk, threatens life. The partial form is not usually fatal, but it may pass into the general form, and thus ultimately cause death; it begins either in the hand or in the shoulder, generally of the right side, and may destroy many muscles of the upper extremity, while in the general form all the voluntary muscles throughout the body may suffer, with the exception only of those of the eye-ball and of mastication.

When the disease begins in the hand, the muscles of the thumb are generally the first to become attacked; the thenar eminence becomes replaced by a flattened hollow space between the first and second metacarpal bones; afterwards the interossei and lumbricales and the hypothenar eminence become affected. From the hand the disease spreads to the fore-arm, the extensors of which are especially liable to it; but the flexor muscles may also be destroyed, and in this case the two last phalanges cannot be bent, so that the patient is unable to grasp or seize anything with the hand. In other instances wasting palsy first invades the muscles of the shoulder, attacking with preference the trapezius, serratus, the rhomboidei, and other muscles which connect the scapula with the trunk; the scapula is consequently displaced and twisted round its axis, its upper angle being depressed by the weight of the arm, while its lower angle is raised, and projects one or two inches from the surface of the thorax. From the shoulder the disease spreads towards the arm, destroying the deltoid and biceps; owing to which the acromion and coracoid process become prominent under the skin, and serious functional disturbances follow. Although the patients generally learn in the course of time to manœuvre cleverly, so as to compel muscles which have escaped destruction to do the work of those

which are wasted, they are at last no longer able to raise the arm nor to bend the elbow; they can neither dress nor feed themselves, and experience considerable difficulty in putting on a hat or drawing a handkerchief from the pocket. If the muscles of the lower extremities are attacked, walking becomes difficult; and at length paralysis follows. The muscles of the chest, chiefly the pectoralis major, become affected in their turn; the chest appears shrunk, especially beneath the collar-bones.

A certain sign that the disease will shortly prove fatal is destruction of the facial muscles; the physiognomy loses all expression; the saliva flows involuntarily; articulation becomes slow and difficult; and finally, the muscles of deglutition and the diaphragm lose their power. This generally closes the scene, as the slightest impediment to respiration which may supervene produces asphyxia.

No medicinal treatment appears to do the least good in progressive muscular atrophy, and treatment by the constant current is the only proper one. Faradisation has been fairly tried during the last fifteen years by many observers, but has been found wanting, more especially in the general form of the disease; while, if the continuous current is used with perseverance, the patients may recover even after the disease has reduced them to utter helplessness. A local application of the current to the muscles may be combined with galvanisation of the cord and the cervical sympathetic.

Dr. Neumann,[1] of Magdeburg, has published a most instructive case of this affection, which had proceeded to paralysis of all four extremities, and yielded to the use of the continuous current. The patient was a youth, aged 19, who had had the measles in July 1866, and, after recovering from them, had felt unable to do the same amount of physical work as before. He went on comparatively well, however, till he over-exerted himself considerably one day, after which symptoms of atrophy and paralysis supervened rapidly, the patient becoming completely paralysed within a month. He came under treatment in October 1866, when he could move neither his arms nor his legs. There were the usual fibrillary twitches, but no anæsthesia. The diagnosis was rendered certain by harpooning a piece of muscle, and examining it microscopically, when the diameter of the muscular fibres appeared diminished; there were plenty of fat-globules of

[1] Berliner klinische Wochenschrift, September 14, 1868.

different size, and the transverse stripes were mostly gone. In December 1866, the patient could not make any movement except flex the fingers very slightly, nod his head, breathe, and masticate and swallow his food. The expulsive power of the bladder and rectum remained normal. Electro-muscular contractility was considerably diminished, but the appetite, digestion, and sleep were excellent.

At first the induced current was applied to the muscles, but as the patient got worse under its use, the continuous current of twenty cells of Daniell's battery was directed to the sympathetic, the positive pole being on the nape of the neck, and the negative on the throat, five minutes at each side, for three months every day, and then the negative pole was applied to the upper cervical ganglion, and the positive to the lower ganglion, likewise for five minutes each time. After a week's treatment the patient felt stronger in the extremities; and in a few weeks more a real increase of power could be ascertained, at first in the legs, and then in the arms. In May 1867, he could walk, although still in an awkward manner. In September 1867, the muscles were again examined, and still found in a state of fatty degeneration. In October 1867, the patient could put a piece of bread in his mouth. From January 1868, the improvement began to progress rapidly, and in April the treatment was discontinued. In May the muscles were again microscopically examined; it was found that there were only very few oil-globules, and that the transverse stripes had re-appeared, but that they were not yet quite so distinct as they are in health. The intra-muscular nerves were found perfectly healthy.

This case was remarkable by its rapid progress, as the disease became fully developed in two and a half months, the paralysis being proportionate in degree to the atrophy, and both corresponding in extent to the degree of electro-muscular contractility.

XIII.—DIABETES.

Whatever may be the nature and causation of diabetes, there can be no doubt that the parts forming the floor of the fourth ventricle, and more particularly the roots of the pneumogastric nerves, play an important part in its production and continuance. It is likewise certain that the continuous current, when applied to the pneumogastric, is transmitted to the floor of the fourth ventricle, and galvanisation of the vagus seems therefore to be a rational remedy for diabetes.

Signor Mariano Semmola[1] states that electrisation of the vagus, both by the continuous and induced current, causes, in diabetic patients, a diminution of the quantity of sugar excreted, and sometimes also of the quantity of the urine. The results of the treatment are said to be either temporary or permanent. Where the patients recover, he believes them to have suffered from an idiopathic neurosis; but where the results were temporary, he suspects the presence of structural lesions in the fourth ventricle.

XIV.—RHEUMATISM AND RHEUMATIC GOUT.

In acute and chronic rheumatism of the muscles, both faradisation and galvanisation are invaluable remedies. I have cured many cases of long standing by one or two applications. Rheumatic effusions in the joints are likewise amenable to faradisation and galvanisation, but require a longer treatment than muscular rheumatism. Muscular contractions after rheumatism, which frequently resist a purely medical treatment, generally yield to galvanisation.

CASE 57.—T. C., a musician, aged 31, had, during a tour in Scotland, in the summer of 1859, contracted severe rheumatism in the right shoulder and arm, which prevented him from following his occupation. He had followed various courses of treatment, and taken large quantities of nitre, bicarbonate of soda, iodide of potassium, and guajac. The pain was relieved after a time, but it never entirely left him, and a considerable contraction of the flexor muscles, both of the arm and fore-arm, remained, for which all remedies proved useless. He consulted me in September 1861, when I found the arm in the following condition:—There was some anæsthesia in the arm, for the patient did not feel the prick of a pin, nor could he distinguish the two points of the æsthesiometer when held at the usual distance. He complained of a dull aching pain, which at times became acute, and was very severe when he got into bed. The fingers were very numb. The biceps and brachialis internus muscles were so contracted that the arm was flexed in an angle of about 65°, and could not be extended; the flexor digitorum communis was also rigid, although in a less considerable degree, and the interossei and lumbricals were so much wasted, that the hand

[1] Comptes rendus, 1861. Vol. liii. p. 399.

was nearly useless. The bulk of the arm was considerably diminished, being only eleven and a half inches at a point eight inches downwards from the acromion, and only nine inches at a point three inches downwards from the olecranon; the corresponding numbers for the left arm being thirteen and ten and a quarter. The general health of the patient was tolerably good, but the appetite was indifferent, and the urine was loaded with urates. I prescribed Vichy water to be taken internally, and faradisation and galvanisation of the right arm. The result of this treatment was most satisfactory. In the course of a week the pain disappeared. Soon afterwards, the rigidity of the muscles began to subside, sensation was re-established, and the right arm increased so much in bulk, that after three weeks it equalled the left. In the meantime the urine had, by the use of Vichy water, become normal, and the appetite was much better. The interossei and lumbrical muscles were most stubborn, and only showed signs of improvement at the end of the third week. They then rapidly regained power, and a fortnight afterwards the patient was in excellent health, and able to resume his avocation.

CASE 58.—*Rheumatism of the Deltoid Muscle.*

Dr. T., aged 47, had been a sufferer from rheumatism in the left shoulder for more than seven years, when he came under my care (1857). He had tried almost every means for the relief of the pain, which, especially in autumn and winter, became very troublesome; he had also used magneto-electricity, applied in the old-fashioned way of sending the current through both arms, but without any beneficial effect. I faradised the skin, and after two applications the pain was gone, and has not since returned.

Lumbago, which is a rheumatic affection of the muscles of the loins, yields readily to galvanisation and faradisation. If the latter be used, it should not be for less than twenty minutes at a time, and it may be repeated two or three times the same day, if necessary. The constant current need only be employed for five or ten minutes at a time, and we should place the anode to the most sensitive point.

CASE 59.—*Rheumatism in the Hands and Fingers.*

A spinster lady, aged 76, was sent to me by Dr. Peter Allen, in November 1871. She had for many years suffered from

rheumatic swellings and pain in the joints of the thumb and other fingers, principally of the right hand, and also from loss of power in the hands and fingers. She experienced considerable difficulty in picking up little things, and on using the hands the pain became so much worse that she was prevented from doing any work, which was a great privation to her, as she was of a very active disposition. She also complained of disturbed sleep, loss of energy, and impaired memory. After a short treatment, which consisted principally of the application of the constant current to the spinal cord, the cervical sympathetic nerve, and to the nerves and muscles of the hands and fingers, the patient felt better in every respect. Her nights were very comfortable, her memory improved, the hands and fingers felt much stronger, and she was a great deal more brisk and energetic. Considering the age and general condition of the patient, this might at first sight have appeared an unpromising case; but a marked improvement took place after the first application of galvanism, and the final result was most satisfactory.

Rheumatic gout consists of a nutritive disturbance of the joints which is peculiar to old age, or premature old age. By far the largest number of cases of this disease are observed after the age of 45; and although instances of it occur in much younger persons, yet we invariably find, when such is the case, that emotions, anxiety, privations, voluntary or involuntary offences against the laws of hygiene, and other debilitating influences, have produced a sort of premature *senile decay* in the persons thus affected. The morbid process which under these circumstances takes place in the joints, is very analogous to the atheromatous process which occurs in the internal tunic of the arteries at the same period of life, and which nobody thinks of putting down to a special poison generated in the system. It constitutes one of those highly insidious and chronic inflammatory conditions which are characteristic of the period of involution and senile decay.

This peculiar kind of inflammation, which, if it occur in the synovial membrane and the articular cartilages, we call rheumatic gout, or rheumatoid arthritis, or arthritis deformans, and which, if observed in the intima tunic of the arteries, we call endo-arteritis deformans, or the atheromatous process, never seems to lead to suppuration, as it is not intense enough for that. The first thing that occurs in the joints is hyperplastic proliferation of all the parts involving the same. The synovial membrane throws out,

partly, somewhat large pediculated polypi, consisting of fat and connective tissue, and partly a finer kind of tufts and fringes, causing a peculiar roughness of the surface, which Volckmann has appropriately likened to a sheep's-skin. The cartilages likewise become proliferated, at first in their superficial and external layers, and subsequently in their deeper parts. The natural consequence of this tissue-change is, that the joints are no longer able to stand the wear and tear, either of motion or of pressure, which is put upon them. The structure, therefore, gradually perishes, and proliferation continues only at the edges of the articular cartilages. There is, however, no uniform swelling there, but numberless small nodes are formed, which are as many ecchondroses, and which gradually coalesce to form a sort of wreath round the joint. The surface of the bone thus becomes gradually denuded. This, however, does not cause caries, but ostitis, terminating in sclerosis; and the bone becomes covered with a smooth, shining, white, and firm osseous plate, on which traces of the mechanical injuries to which it has been exposed during life may often be discovered. This brittle osseous tissue cannot, in the nature of things, resist in the long run the constant friction and grinding to which it is exposed, however quiet the patients may keep, in order to avoid the pain which is caused by every motion. If two pieces of pumice-stone were constantly rubbed against one another, only little would be left after a time; and in a similar manner the surface of the bone gradually wastes away. Whole epiphyses may thus perish; the neck of the femur will disappear: and the affected joints will altogether be so deformed that only little, if anything, is left of the original structure.

Looking, then, upon rheumatic gout as a disease of malnutrition peculiar to the period of involution and senile decay, we must not be led away by the term 'inflammation' into antophlogistic measures, which only make matters worse; but the great aim of our treatment should be to support and stimulate the failing powers. The remedies upon which chief reliance is placed by the best observers, are therefore bark, mineral acids, strychnia, iron, cod-liver oil, and arsenic. There can be no doubt, from the positive statements of reliable practitioners, that in a considerable proportion of cases these remedies do a great deal of good: yet how frequently do we see patients who have for months and years been under the care of the most eminent

physicians, familiar with all the ordinary resources of the art; who have had everything done for them which money can procure; who have not only taken gallons of physic, but paid one visit after another to Buxton, Bath, Wiesbaden, and Wildbad, and who yet find the distressing symptoms of their complaint gradually becoming intensified, the pain more severe, the deformity greater, the helplessness more embarrassing. Surely under such circumstances we cannot look with any degree of satisfaction upon our present treatment of rheumatic gout: and any means which promises, from general considerations, to be really effective in such cases, should have a fair trial given to it.

Holding these views, I have lately sought and found many opportunities of using in this distressing distemper that most active stimulant of nutrition, the continuous current; and, although I am far from considering it a specific or a panacea for all cases of rheumatic gout, yet I have seen enough of its effects to convince me that in cases where the most approved lines of medicinal and hydrotherapeutic treatment, intelligently and perseveringly followed, have, after months and years of trial, left the patient no better but rather worse than before, the constant current, judiciously administered, may do great good in a variety of ways. I do not mean to say that we can by its aid really cure rheumatic gout. The current cannot reproduce wasted cartilages, nor restore its normal structure to a sclerosed bone; it cannot prevent the patients from advancing in age, nor arrest altogether the process of involution and senile decay to which the system must in the end succumb; yet it can do much good. The following is a summary of the results of my experience about the therapeutical capabilities of the current in the disease now under consideration.

1. It acts as a general tonic to the system, and more especially to the nervous system. Although in some cases of rheumatic gout the appetite is tolerably good, the food taken is pretty well digested, and the action of the liver, the alvine evacuations, and the urinary secretion, are not very materially interfered with, yet we find that the large majority of patients suffer from some form of dyspepsia and impaired action of the liver, bowels, and kidneys. In the cases to which I now allude, there is no actual disease of these organs, which sometimes becomes developed towards the end; but there is functional debility, owing to an insufficient supply of nervous force to the parts mentioned.

Thus an insufficient quantity of food is taken; that which is taken is imperfectly digested; the elimination of effete matters from the system is slackened; and the consequence of all this is a degree of debility which is more alarming to the experienced observer than the discomfort and pain attending the local manifestations of the disease in the joints. Patients of this class have often considerable difficulty in taking medicinal tonics, which are apt to heat the system, while alteratives often lower it still more. Under such circumstances the constant current is often remarkably effective in rousing nervous energy and improving all the most important functions of the body. The best mode of application for this purpose is to direct the anode, armed with a conductor of large surface, to the cervical spine, while the cathode, similarly armed, is placed on the pit of the stomach. A gentle current, which even patients of exquisite sensibility can well bear, is thus allowed to flow for from three to five minutes in the direction just described. By this application the base of the brain, the spinal cord, and the solar plexus of nerves, are simultaneously brought under the influence of the current.

2. *Want of sleep* is one of the chief complaints of patients suffering from rheumatic gout. This arises partly from want of exercise in the open air, and partly from the circumstance that the pain is apt to get worse at night. The patient keeps tossing about in bed from being unable to find a really comfortable position. 'Nature's sweet restorer' thus flees the pillow of the sufferer, who generally dreads the night as his worst time. Opium and morphia are rarely applicable in these cases, as they generally excite rather than soothe, and impair the action of the stomach and the liver still more. Hydrate of chloral often steps in as the right thing in the right place; but we frequently find cases in which the system does not tolerate it, either in small or large doses. Where morphia and chloral fail to procure sleep, few other drugs will succeed in doing so; and it must therefore be looked upon as a considerable advantage connected with the use of the constant current, that under its influence sleep soon becomes prolonged and refreshing. No special application is necessary for attaining this end, the one I have just mentioned being quite sufficient.

3. *Pain* is another invariable symptom of rheumatic gout, and one which frequently resists the administration of sedatives and counter-irritants. Even subcutaneous injections of morphia and

atropia have only a temporary effect, which rarely extends beyond twelve or twenty-four hours. The pain is generally most severe in the deformed joints, but is likewise felt in many other parts of the body. For the alleviation of the pain, the constant current is the most useful remedy with which I am acquainted. It must in this instance be applied to the suffering parts, so that the positive pole, armed with a small electrode, is made to touch the sore points ; while the negative, connected with a large electrode, is placed in the neighbourhood. The current used may in this instance be somewhat more powerful than where it is employed for general tonic effects ; and if a short application, say of one or two minutes, be not successful, this may be extended to four or five minutes. The effect is, in many instances, almost magical, inasmuch as pain, which has been fixed in some particular spot for months and years, is, as it were, charmed away by one or two applications.

4. The *deformities* which rheumatic gout produces, more especially in the interphalangeal joints of the hands and feet, resist the use of the current more obstinately than the other symptoms which have been mentioned; and it requires much patience and perseverance on the part of the practitioner and the patient to reduce them to any extent. Provided, however, that the galvanic treatment is followed up for a sufficient length of time, even extensive deformities may be improved, which is a matter of considerable importance, as most patients belong to the female sex. No one who has not seen it can have any idea of the beneficial effects which the current will produce in the long run on these deformities, even where they are extensive, and where the patients are not very old. It seems as if the action of the vasomotor nerves were gradually directed back into its proper channel. Unfortunately, many patients want to be cured in a week of a disease which is essentially chronic in its progress; and some practitioners are inclined to discontinue a special treatment too soon, unless immediate effects are produced by it. In this, as in many other complaints, the ultimate success of a particular plan of therapeutics depends not alone on the remedies which are used, but also very materially upon the more or less systematic use made by the practitioner of his remedies; and last, not least, upon the intelligent co-operation of the patient. In order to reduce deformities, galvanisation of the cervical sympathetic nerve must be had recourse to.

By what I have said I do not by any means wish to imply that

the use of internal remedies should be altogether eschewed in the treatment of rheumatic gout. If we were, for some reason or another, to abstain completely from their use, we should only deprive ourselves of many chances to do good to our patients. Although in the system of therapeutics which I have pursued for rheumatic gout, I have given the first place to the constant current, I have frequently prescribed medicines which I thought would prove beneficial for removing certain complications which were present. Thus, where there was an excess of acidity in the system, as evidenced by a highly acid condition of the mucous membrane of the tongue, the perspiration, and the urine, I have given alkalies or bismuth; for constipation, I have ordered Marienbad or Friedrichshall mineral water; where the blood appeared to be very much impoverished, the ferrum redactum of the Pharmacopœia, or Spa water, was prescribed. All these and some other remedies I have used were, however, only auxiliaries of the galvanic treatment, and could not of themselves have exerted any decided influence upon the progress of the disease.

The circumstance that most of our patients are above 45, and not a few above 60 years of age, in connection with the obstinate character of the malady itself, must prepare us for slow results, more especially as far as the improvement of the deformities is concerned. Pain, indeed, is often relieved at once, but it is very apt to return: the patient often becomes rapidly stronger, but at times the old debility will again be felt, more especially if he undertake to do more, either in business or pleasure, than he is able to do; and a sleepless night may again occur after many good nights in succession. It is therefore necessary to tell the patient at once that a rapid cure is quite out of the question. The current should be used, either daily or three or four times a week, for at least a month or six weeks; and if the patient continue to improve, we may go on with it much longer than that. If, however, after that time he does not seem to make any further decided progress, it is better to discontinue the treatment for a month or longer, and then to recommence it. Those who will not shirk the sometimes rather tedious labour involved in carrying out such a treatment perseveringly, will ultimately be amply rewarded for their trouble by an amount of success which, in some forms of the disease, could not have been obtained by any other line of treatment.

Hydrarthrosis.—M. Van Holzbeck has recorded two cases of dropsy of the knee-joint, which were cured by him with electro-

puncture. He put two needles in the sac, connected them with the poles of an induction machine, and sent the current through the knee for a quarter of an hour. He says that the effusion was at once diminished, and next morning the swelling had disappeared. He now put a bandage on, and repeated the operation once more. The cure was complete and permanent.

In mild cases the external application of the constant current is sufficient; while in severe ones either farado-puncture or the electrolytic treatment is preferable. The magneto-faradic current appears in this disease to be more effective than the volta-faradic.

M. Tripier[1] has treated a case of hydrarthrosis of the knee, of six weeks' duration, in which there was considerable effusion in the joint. A current of forty-four small cells of the protosulphate of mercury battery was applied by large moistened electrodes to the sides of the knee, for twenty minutes. After two such applications the effusion had disappeared.

Dr. Lange[2] has cured a case of *œdematous swelling of the feet* with the aid of the constant current:—

A printer, aged 32, complained, after a long walk, of a burning sensation in both feet. Being obliged to work in a standing position, severe pain came on, and the joints became so swollen as to be twice their usual size. He used Russian baths, local vapour baths, blisters, colchicum, iron, quinine, and iodide of potassium, without much benefit. He could only walk by the aid of two sticks. He continued in this state for three years. The joints were then tender and stiff, and double their normal size. The general health was tolerably good. A current of thirty cells was now sent for twenty minutes continuatively through the left foot. The next day the foot was less painful, and the patient could step out more easily. Each foot was now galvanised for fifteen minutes at a time, and intermittent galvanisation of the nerves and muscles of the leg combined with it. A rapid improvement followed. The pain and swelling diminished, and after ten days the joints were freely movable. In three weeks the patient could walk as well as before.

[1] Manuel d'Électrothérapie, p. 282. Paris, 1861.

[2] Deutsche Klinik, Mai 9, 1868.

XV.—DISEASES OF THE EYE.

I have already spoken of the electric treatment of paralysis of the motor nerves and muscles of the eye (p. 556), of amblyopia, amaurosis, and weakness of sight (p. 584), and of photophobia (p. 608). A few words now remain to be said on the use of electricity in opacities of the cornea, and in cataract.

1. *Opacities of the cornea.*—The slighter kinds of opacities, which are termed *nebulæ*, yield readily to the application of the continuous current, while thick opacities (*leucoma*) are more obstinate. These are due to more or less severe inflammatory changes in the corneal and epithelial cells. Opacities which are due to cicatricial hardening are incurable. A host of local remedies have been recommended for the cure of opacities, and amongst them electricity. In 1844 Signor Isiglio, of Corfu, treated some cases successfully with it. Signor Quadri of Naples, M. Willebrand of Helsingfors, and Dr. Türck of Strasbourg, followed in his steps; and Professor A. Von Graefe states, that in a case where both corneæ were opaque, he employed electricity on one eye, and nitrate of silver or laudanum on the other, and that electricity was more rapidly successful than the chemical irritants. Mr. Soelberg Wells[1] says that electricity was formerly in vogue for the cure of these affections, but has now fallen into disuse. No doubt there are many other means by which these opacities may be removed; but I am inclined to think that electricity is in some cases more useful than chemical or mechanical irritation. The treatment of opacities by faradisation is no doubt tedious, but the constant current is more rapidly successful; and it is well known that oculists have not yet given a fair trial to the constant current in this affection. It may be applied either to the closed eyelid, by means of a moistened sponge, or by a blunt gilt or silver conductor directly to the cornea. In the latter instance a very gentle current should be used, and the application must be short. Where the current is applied externally, the operation may be longer and stronger.

Case 60.—H. T., aged 19, received in May 1862 a violent blow on the left temple from a cricket-ball. He was at first quite stunned, and felt great pain in the head for several days afterwards. The conjunctiva and cornea of the left eye then became

[1] Loc. cit. p. 126.

inflamed, for which the patient was put on a course of mercury; but although his system was much affected by that drug, the eye did not get better. Mercury was therefore given up after a time, and other treatment resorted to. The inflammation gradually subsided, but a considerable opacity remained, which covered the whole extent of the cornea, and was thickest in the lower portion of that membrane. Vision was almost entirely prevented by it. Mr. White Cooper, whom the patient consulted in July 1862, thought that electricity would be the best means of promoting the absorption of the opacity, and sent him to me. I combined faradisation with galvanisation, the cathode being directed to the closed eye, and the anode to the temple, so as to stimulate the influence of the first branch of the trigeminal nerve upon the nutritive processes in the eye. The patient quickly improved under this treatment; and when it was discontinued after twenty-four applications, there remained nothing but a very thin film on the cornea, which was only perceptible on close examination, and impeded vision scarcely at all. A cure would probably have resulted, if the patient, who did not live in London, had been able to pursue the treatment a little longer.

2. *Cataract.*—Crussel and Lerche[1] have endeavoured to dissolve cataract by the aid of electricity. They found that if the zinc pole of a voltaic pile was applied to a lens, this was rendered opaque; and that the opacity disappeared on directing the copper pole to it. Hence they concluded that it might be possible to dissolve cataract by the application of the negative pole of the pile to the eye. Matteucci[2] states that cataract cannot be dissolved by electricity; but we have the authority of Dr. A. Von Graefe[3] for the contrary. A few cases of cataract have been treated by Crussel with galvano-puncture, but the operation was followed by inflammation of the chorioidea, iris, and retina, resulting in ultimate destruction of the eyeball, and is therefore unjustifiable.

XVI.—DISEASES OF THE DIGESTIVE ORGANS.

I have already spoken of the galvanic treatment of loss of taste (p. 589), and difficulty of swallowing (p. 568); and now

[1] Medizinische Zeitung des Vereins, etc. 1841.
[2] Cours d'Électrophysiologie. Paris, 1858.
[3] Deutsche Klinik, 1852, p. 445.

proceed to mention some other affections of the digestive tract in which electricity may be of service.

Dyspepsia.—In some forms of dyspepsia galvanisation of the sympathetic nerve, the stomach and intestines, is useful, and this is more especially the case with 'nervous indigestion.' A special form of dyspepsia, which is connected with increased elimination of urea, has already been considered.

In cases of *over-eating*, or where *poisons have been taken into the stomach*, we may, by faradisation, cause the evacuation of the ingested matters either by the stomach or the bowel.

Dr. Charles Fox,[1] of Birmingham, has used what he calls *galvano-emesis* in a case of two children who had eaten poisonous fungi. They were in a state of collapse, almost pulseless, unable to swallow, with the jaws set, and frothing at the mouth. None of them had vomited. One of them was apparently dying; and he was preparing to assist failing respiration by faradism, when the thought struck him that, if he could by the same means excite contraction of the stomach, vomiting would probably ensue. He therefore passed one of the poles by a suitable conductor to the top of the œsophagus, and applied the other by a wet sponge to the epigastrium. Vomiting was immediately produced in both cases, and a quantity of the fungus was rejected. The children were insensible to the vapour of the strong liquor ammoniæ; it could not, therefore, have been the mechanical irritation which caused the vomiting. Both children recovered.

M. Bonnet caused, in a somewhat similar case, the evacuation of matters by the rectum.

He was called to see a girl who had eaten an enormous quantity of figs, and became convulsed and unconscious the night after. Her pupils were dilated, the pulse small and rapid, the jaws firmly clenched, and the abdomen hard and full. Cold fomentations to the head and three purgative enemas had produced no effect. M. Bonnet then introduced the positive electrode of an induction apparatus into the rectum, and placed the negative on the abdomen. The muscles of the abdominal parietes immediately began to contract; after two or three minutes the positive electrode was hurled out of the rectum, together with an enormous quantity of undigested figs and fæcal matter. The girl at once recovered her consciousness, and was quite well on the following day.

[1] British Medical Journal, vol. ii. 1872, p. 493.

Obstinate vomiting, from whatever cause, is often promptly relieved by faradisation.

M. Popper [1] has thus treated a girl who had for a long time suffered from vomiting immediately after her meals, and was likewise troubled with meteorism. The abdomen was very sensitive to pressure, and the bowels habitually costive. After a great many remedies had been used without avail, faradisation was used, both electrodes being placed on the stomach for five minutes. The girl was then allowed to eat, and retained her food. Twelve more applications effected a cure.

Drs. Beard and Rockwell have described a case of nausea and vomiting, which recovered under galvanisation of the sympathetic, after failure of general faradisation. The patient, aged 40, was of slight build, and of a thoroughly nervous organisation. There was no evidence of organic disease either in the history of the case or in the special character of the symptoms. The attacks of nausea and vomiting came on usually in business hours, and could not unfrequently be referred to mental anxiety. A strong evidence that the disease was mainly functional in its character was that on Sabbath-days, when the patient did not go to his office, and was free from business cares, he was free from the attacks.

Ordinary treatment, both by medication and by electricity, carefully and perseveringly employed by the usual methods, had failed to give substantial relief. As a last resort, it was resolved to use the proceeding known as galvanisation of the cervical sympathetic. The result was immediate and favourable; from the first application the patient began to improve, and in three weeks he regarded himself as cured.

Although *sea-sickness* is probably a disorder of the nervous system, it may find a place here, on account of its principal symptoms being sickness and vomiting. Dr. Dwinelle [2] has given an account of M. Le Coniat's mode of treating sea-sickness by faradisation of the stomach. He first applies a solution of sulphate of atropia (a grain to the ounce) over the skin of the stomach; but it is not said how this solution is applied, nor how much of it is used. After this he puts the negative electrode of an induction apparatus terminating in a flat disc, over the skin corresponding to the pyloric end of the stomach; and he then

[1] Oesterr. Zeitschrift für practische Heilkunde, 1865, p. 365.

[2] New York Medical Journal, 1869, p. 390.

passes the positive electrode terminating in a moist sponge, across the skin from the cardiac to the pyloric orifice, when the muscles are seen to contract vigorously. The effects are soothing and refreshing, and generally accompanied with drowsiness, followed by refreshing sleep. M. Le Coniat claims to cure by this proceeding, at least ninety per cent. of the patients suffering from sea-sickness; and believes himself able to control the vomiting and sickness of pregnancy by the same. Dr. Dwinelle mentions the case of a lady who crossed over from Brest to New York, and who suffered from the worst form of sickness; the vomiting and retching having, on the second day, been followed by convulsions and extreme prostration. By one application of atropia and electricity the sickness was arrested; the lady began to eat with a relish, and kept perfectly well until her arrival at New York. Most of the passengers by the same steamer suffered from sea-sickness, and were freed from it by one or two applications. The atropia is probably quite ineffective, as no mention is made of subcutaneous injection, and the unbroken skin would not absorb the solution. Faradisation acts in this instance as a nervous alterative.

In cases of *constipation* caused by insufficient peristaltic motion of the contractile fibre-cells of the intestines, and by loss of power in the abdominal muscles, electricity may be useful, especially if the affection occurs after protracted diarrhœa, the abuse of aperient medicines, and in cerebral and spinal disease.

There are so many means for the relief of constipation, that electricity will probably, as a rule, be required in very obstinate cases only, or where the patient himself has a particular wish for such a treatment. This latter is particularly the case where patients have for years been dosed with purgatives, and become hypochondriacal in consequence.

A good proceeding is to put one faradic conductor to the lumbar spine, and press the other one firmly against different points of the abdominal parietes, so as to cause powerful contractions of the abdominal muscles, and of the muscular coat of the bowel. I prefer using the abdominal conductor in the anatomical direction of the bowel, so as to commence at the sigmoid flexure, at the lower part of the abdomen, then to proceed gradually upwards to the right hypochondrium, follow up the colon transversum, and at last act on the colon descendens. Direct faradisation of the rectum is very effective, but more disagreeable.

CASE 61.—A single lady, aged 43, tall, of sallow complexion and sedentary habits, consulted me in February 1866, for a 'nervous affection,' from which she had suffered for many months past. She complained of a constant dull headache, of giddiness on rising in the morning, a wearying feeling of mental depression, and frequent flushings of the face and ears. Her hands and feet were habitually cold. Her sleep was disturbed and too short, for she slept on the average only two or three hours a night. Her intellect and memory were as good as ever, but she found it difficult to fix her attention on any subject, and felt a distressing sensation of pressure on the head after reading or writing. The latter circumstance annoyed her a good deal, as she had been a zealous supporter of various philanthropic undertakings which required a considerable amount of correspondence. She was sometimes troubled with palpitations of the heart: the heart's sounds were weak; the pulse small and feeble. The breath was generally short; the chest otherwise healthy. The tongue was dry, and covered with a yellowish white coat. The appetite was feeble, and digestion tedious and painful. For many years past the patient had suffered from obstinate constipation, for which she habitually took purgatives. If she attempted to do without them, she felt great pelvic distress, especially in walking and standing, and considerable increase of all the head symptoms. She had taken cremor tartari, aloes, nux vomica, colocynth, scammony, and podophyllin. The evacuations were hard and ill-formed. The urine was generally scanty and turbid, and she had often a scalding sensation in passing it. She had a small fibroid tumour of the uterus, for which she had consulted several obstetric physicians, who had advised that it should be let alone. At the time of the catamenia her sufferings increased very much. Purgatives then seemed to augment the menstrual flow to an alarming extent; it often, in fact, amounted to true menorrhagia, which lasted for ten or twelve days. She therefore took smaller doses of aperients during that time; with the effect that the loss of blood was not so copious, while, on the other hand, the pain and discomfort about her head were so dreadful that she often thought she would lose her senses. Her habitual dose was now two teaspoonfuls of cream of tartar twice a day, and ten grains of compound colocynth pill at bed-time.

As she had lived too exclusively on meat diet, I ordered her to

take boiled fruit and saccharine vegetables; to discontinue the cream of tartar entirely; to take five grains of compound colocynth pill at bed-time, and a tumblerful of Marienbad water twice during the day; and finally to take as much exercise in the open air as possible without fatigue.

February 25.—Has found great relief from the change in her diet, and from the Marienbad water. Last period was more comfortable than it had been for many months past. Has not been able to take much exercise, because it brought on palpitations of the heart. Ordered to go on as before, but to take the colocynth pill only every other night.

March 18.—Has been worse for the last week or ten days. The Marienbad water seems to have lost its effect. Has been obliged to take ten grains of colocynth pill daily for the last few nights. Head most uncomfortable; extreme depression of spirits. I now substituted Friedrichshall for Marienbad water, and allowed her to take five grains of colocynth pill every night.

April 20.—The last period was just as bad as ever. The Friedrichshall water only relieves constipation when taken in large doses, which she believes to be lowering, and is ineffectual as soon as the dose is reduced. I now proposed to the patient the application of faradism for inducing a healthier action of the bowels; and as she consented at once, I sent a current of moderate power for fifteen minutes through the intestines. The patient did not complain of any pain or discomfort from the application, but said she felt more exhilarated and hopeful than she had done for a long time.

24th.—She came to me in high spirits, saying that since faradisation was used she had every day had a better motion than for many months past. I ordered her now to discontinue the colocynth pill entirely, and merely to take a wineglassful of Friedrichshall water twice a day.

From that time forward the patient made an uninterrupted recovery. Faradisation was continued twice a week for a month, after which the bowels acted well without assistance. The head symptoms disappeared gradually in proportion as the action of the bowels was restored; and when I last saw the patient (July 1867) she was perfectly well, excepting the somewhat too copious menstruation, which was now the only trouble she experienced from the fibroid tumour of the uterus.

Tympanitic distension of the abdomen is owing to intestinal

atony, and loss of power in the abdominal muscles; the bowel, therefore, meets with no resistance, and becomes considerably distended. This condition is frequently observed in hysterical women; after partaking of indigestible food; in acute diseases, especially typhus, pneumonia, small-pox, puerperal fever, peritonitis, &c. A high degree of tympanites threatens life, as it may give rise to asphyxia, by paralysis of the diaphragm, and compression of the lungs. A purely medicinal treatment often fails to relieve it, and faradisation or galvanisation should be employed if the affection do not yield readily to other remedies.

Various methods of applying electricity have been resorted to. M. Becquerel has placed the positive electrode of the faradic instrument in the mouth, and the negative in the rectum; and has never seen any benefit from it. The method is therefore not to be employed, as it is both painful and useless. Either of the methods just mentioned as useful for constipation may be resorted to. The best way is faradisation or galvanisation of the rectum (pp. 343 and 427).

CASE 62.—*Extreme Meteorism after Ovariotomy.*

A married woman, aged 37, mother of one healthy child, twenty-two months old, came from Aberdeen to London, in April 1863, in order to consult Mr. Spencer Wells for a large ovarian tumour, which had begun to form in July 1862, and had rapidly increased after August of the same year. The patient had a dark and rather sallow complexion, and had become much emaciated during the last two months. The tongue was clean, the appetite pretty good, the bowels were naturally open, but she complained of troublesome flatulence. The breathing was only slightly affected; there was no cough and no expectoration. The catamenia had ceased in September, 1862. The pulse was at 120. The girth at the umbilical level was forty-nine inches. She had been tapped seven times, but had always refilled rapidly. Mr. Wells performed ovariotomy upon her on April 29. There were strong and extensive parietal adhesions, both anteriorly and laterally; thirty-three pints of fluid were removed, and the cyst and solid matter taken away weighed thirteen pounds thirteen ounces. Without going further into the details of the case, I will only say that the patient went on fairly, excepting an immense distension of the stomach and bowels by gas, which was so great as to threaten life. After the most efficacious medicines

had been taken without improvement, Mr. Wells believed that faradisation was necessary, and requested me to see the patient. I saw her on May 18, when the flatulent distension was so great that the left lung was almost entirely compressed, the heart being dislodged to the right side, and there being tympanitic sound in the second intercostal space. I performed faradisation, after which the patient had a considerable discharge of flatus. On May 19, I repeated the operation, and the patient then had two motions, one of them solid. I operated upon her four times more, after which the lung had again expanded to its normal volume, and the patient being nearly well, the treatment was discontinued. On May 26 she went on board the steamer which was to sail the day following for Dundee. The patient died at home in the commencement of August from malignant disease, which had very rapidly formed; but both Mr. Spencer Wells and Sir William Jenner, who had also seen her, were of opinion that if she had not been faradised, she would have died in London from the effects of the meteorism.

Habitual Flatulency.

CASE 63.—A gentleman, aged 46, had dysentery fifteen years ago, and had ever since suffered from flatulency, which was extremely troublesome. He was otherwise in good health, but the flatulency never left him even for a single day, and was so bad after meals, that he was obliged to lie down for an hour or two afterwards. The examination of the abdomen showed no tumour or obstruction, but merely a considerable accumulation of gas in the large intestines. He had used a great many remedies without success, especially charcoal and belladonna. I galvanised the bowel with a current of twenty-five cells, the anode being in the rectum, and the cathode being passed over the abdominal parietes. The patient felt very comfortable for some hours after the first application, and the flatulency only returned in the afternoon. After four more operations he passed a whole day without feeling troubled with flatulence, and after three weeks he was quite free from it.

Faradisation may, like the ether-spray, be useful in cases of

Incarcerated Hernia.

M. Delaux, of Toulouse, has described the case of a woman suffering from femoral hernia, and which became incarcerated

after a violent exertion. She refused to consent to an operation. After three days, when she was rapidly getting worse, he first faradised the hernia itself, and afterwards put one electrode into the rectum, and the other upon the hernia. The tumour now began to move, and disappeared in a short time. Within a few days the patient was perfectly well.

Dr. Mac Cormac, of Belfast, has sent me the particulars of the following cases of *ileus* which have been under his care, and which I give in that gentleman's own words:—

'The first case was that of a brewer. He had been three days ill of ileus, and was sinking rapidly. The pain was great, there was feculent vomiting; and I had tried vainly, in large successive doses, calomel, compound extract of colocynth, castor-oil, opium, turpentine, and linseed-oil injections. The pulse was wretched, the expression of the countenance miserable, and the sufferer had been three days without any sustenance. It then occurred to me to resort to galvanism, which I did with the least possible delay. I stripped the patient, and applied the moistened negative pole to the spine, while I promenaded the other pole here and there over the abdominal surface, but preferably in the lines of the great intestines. The patient, who was standing all the time, winced a good deal. But after the lapse of from about two to three minutes, a sound of flatus in motion could be heard in the course of the tract of the great arch of the colon. The patient called out for the close stool, when he had an enormous evacuation of feculent matters with prompt and permanent relief. He had been previously under my care for an attack of hepatitis, and was of very indifferent stamina. I have not the slightest doubt that galvanism in this instance brought about the resolution of the disease; and, by stimulating into normal activity the peristaltic action of the bowels, saved the patient's life.

'The second case was that of a very much younger man, but was otherwise, although not of so long standing, equally severe as the preceding case. The usual means were resorted to, both by Dr. Archibald Dunlop, under whose charge the patient was before I was called in, and by myself, but in vain. There was this additional feature of severity, too, that large quantities of blood were passed by stool, which, coupled with the ileus, was rapidly exhausting the patient's strength. In this conjuncture of affairs, I proposed galvanism, to which my colleague at once assented. It was very effectively resorted to, and in the course

of the afternoon, not so speedily as in the first instance, though not less effectively, the patient evacuated a large amount of fæces with speedy relief and a lasting recovery.'

Dr. Macario, of Genoa, relates a case of a man, aged 71, who suffered from obstinate constipation and at last became affected with stercoraceous vomiting. The doctor then introduced a metallic conductor into the rectum and passed the other electrode of a faradic instrument connected with a moistened sponge over the abdomen in the region of the transverse colon. Under the influence of faradisation the abdominal parietes contracted violently. The action was kept up for ten minntes; four hours afterwards a copious evacuation took place, which was followed by several others in the course of the night. On the next day the patient was quite well.

Dr. Clemens,[1] of Frankfort, has recommended that in these cases one or two tablespoonsful of metallic mercury should be given, and a continuous current then sent through the abdomen; the negative electrode by means of a large conductor to be applied to that part of the abdomen where the seat of the obstruction is supposed to be, while the positive is in the rectum. Voltaic alternatives should be used, and the current closed and opened three or four times in one minute. The mercury accumulates at the seat of the volvulus, where therefore the effect of the galvanis discharge is more thoroughly experienced than in other parts of the intestinal canal. Dr. Clemens says that he has cured a case of invagination by this means; but Dr. Mac Cormac's cases show that electricity alone, without the mercury, is able to overcome this affection. Where this is owing to organic structure, of course no benefit can be expected.

Prof. Gerhardt, of Würzburg,[2] has recommended to treat *catarrhal jaundice* by faradisation of the gall-bladder, considering it as rapidly effectual in that disease as reduction is in the treatment of hernia. The lower border of the liver is made out by percussion, and it is then not difficult to determine the position of the gall-bladder. Sometimes that organ may be seen or felt as a small swelling, which moves synchronously downward with respiration. In any case, however, a semicircular extension of dulness is found, or a more intensely dull place at the border of the liver, situated between those limits which correspond to the lateral variations in the situation of the gall-bladder. After this point

[1] Deutsche Klinik, No. 25, 1867.

[2] Berliner Klinische Wochenschrift, July 6, 1873.

has been marked, the electrode of a somewhat powerful faradic current is placed on it, and its point pressed moderately firmly in a direction towards the posterior abdominal wall. The second electrode is then rapidly applied to the horizontally opposite side of the posterior abdominal wall. If the current be powerful, an audible commotion of the abdominal organs is caused by the contraction of the abdominal muscles. After a few seconds the electrodes are removed, and then put on again a few times more in the same manner as above. In many cases the disappearance of the dullness of the gall-bladder gives at once a hint as to the result which has been obtained. Success is certain if within the next two days a bilious stool is passed. Generally the vasomotor nerves of the kidneys are excited at the same time, the consequence of which is that the urine which is passed on the next day is paler and more diluted than it was before. As in a few of Gerhardt's cases, the dullness of the gall-bladder re-appeared after a biliary motion had occurred, and it was found necessary to repeat faradisation once or twice.

One of Gerhardt's patients was a brewer, aged 28, who was seized on January 23, 1873, with the symptoms of severe acute gastric catarrh, and was admitted into the hospital on February 5. The conjunctiva was white, but the skin more darkly coloured. On the following day the skin and conjunctiva were perceptibly icteric, the urine contained biliary pigment, and the fæces were colourless. The lower border of the liver was found in the papillary line, half an inch wide below the ribs, in the mesial line just between the umbilicus and the ensiform cartilage, and showed in the middle between these two points the dulness of the gall-bladder projecting inferiorly. On the 7th the jaundice was considerably increased, the appetite gone, and there was frequent retching. On that day the case was lectured upon, clinically demonstrated, and faradisation performed. The urine, which had been of 1·029 specific gravity before, was only 1·023 and much paler in the after part of the day. The appetite was better on the next day, the fæces feebly coloured with biliary pigment, but there was increased itching of the skin. The density of the urine remained at 1·023. As the dulness of the gall-bladder was found to increase again, faradisation was repeated. On the 9th the motions were strongly biliary, the appetite better, the retching had ceased. On the 11th the jaundice was perceptibly less. On the 13th considerably less, and

the patient was better altogether. On the 22nd he was discharged cured. With the exception of a little Epsom salts on the day of admission, and when there was constipation, no medicines had been given.

Another case was that of a student, aged 22, who was admitted on February 17. He had been ill of acute gastric catarrh for a week, having dined shortly after having experienced a considerable annoyance. A few days later the skin became yellow, and on admission the jaundice was intense. On the 18th the gall-bladder was made out by percussion and faradised. The density of the urine fell on the same day from 1·029 to 1·023. On the 20th the patient felt better, the icteric coloration of the skin had perceptibly diminished; the motions contained biliary pigment. He was discharged cured on the 25th.

XVII.—DISEASES OF THE ORGANS OF CIRCULATION.

Aneurism has been frequently treated by galvano-puncture, but although some favourable results have thereby been obtained, the number of failures is much larger than that of successes, so that at present the operation of galvano-puncture is, by most authorities, proclaimed to be an unsafe and unreliable proceeding. Sir William Fergusson, in his 'Manual of Surgery,' curiously enough ignores it altogether. Mr. Erichsen condemns it in unqualified terms. Professor Pirrie remarks that 'the operation is founded on the principle of the galvanic current having the power of coagulating the blood; and that this principle is not sound, as stratified fibre is the substance by which we desire to solidify an aneurism, and not coagulated blood; that the proceeding is also very painful, and not unattended with danger, and the results are not encouraging.' Mr. Ernest Hart, in his article on aneurism in Holmes's 'System of Surgery,' says (vol. iii. p. 432), that 'galvano-puncture is inherently uncertain, liable to cause relapse by the melting of the coagulum, or inflammation by its too sudden deposition, and that it appears at present to deserve to rank only as an exceptional expedient, when the surgeon is called upon to treat either aneurisms at the root of the neck, or internal aneurism which cannot be reached by digital or mechanical compression, and some forms of varicose and cirsoid aneurism seated superficially.'

M. Broca, and many other eminent foreign surgeons, coincide

in this view, and it may be said, therefore, that the proceeding has not established a footing in surgery; nor ought we to be surprised at this fact, since only the worst cases of aneurism, and which cannot be treated in any other manner, are by surgeons reserved for galvano-puncture; viz. those of intra-thoratic aneurism.

Mr. Holmes,[1] in his able Lectures on the Surgical Treatment of Aneurism, delivered at the Royal College of Surgeons, says that 'Our present experience of galvanism in intra-thoracic aneurism shows us that the method may often be used so as to avert death when imminent from the rupture of the sac, and that with that view alone it is a method which well deserves further trial. Signor Ciniselli, of Bologna, who has more experience in this matter than any other surgeon, is of opinion that we must not exaggerate the value of this method. The circumstances which are favourable to a perfect success occur very rarely in practice. In the majority of cases which present themselves, the disease is in too advanced a condition, and should be left alone, because the operation will be useless, and perhaps mischievous. In cases where the most favourable conditions exist may it be possible to obtain consolidation and cure of an idiopathic aneurism; but since the cause which produced the aneurism—viz., an atheromatous condition of arteries—still exists, it may cause a recurrence in another part of the vessel. Admitting this, however, and considering that we are dealing with a malady for which up to the present time no surer remedy has been discovered, I submit that it is a considerable step in the treatment of internal aneurisms to have discovered a method which, employed according to the rules sanctioned by experience, proves innocent, procures a cure even if temporary, alleviates the patient's sufferings, and prolongs his life.'

I have, within the last twelve months, been called upon to treat, or assist in treating, five cases of aneurism; and it is a matter of infinite regret to me that the full notes which I took at the time of all these cases, and which I had intended to incorporate in this volume, should have been accidentally destroyed. I can therefore only give a very short outline of the salient points of each case.

The first case in which I used it, was an *aneurism of the innominate artery opening into the aorta*, in a patient aged 50, who was under the care of Mr. Holmes, in St. George's Hospital. The

[1] The Lancet, July 20, 1872.

tumour was chiefly situated behind the first bone of the sternum, which was much absorbed, and it also extended above the sterno-clavicular articulation for a short distance. Treatment by rest and moderate diet without stimulants, was followed from April to November, but had no effect. Injections of ergotine, acetate of lead, and local cold and compression having likewise failed, Mr. Holmes tied both the subclavian and carotid. The pulsation of the tumour at first diminished slightly, but soon returned to about what it had been before the operation, and it was quite evident that the ligature had had no curative effect. In the last few days of the year it began to grow rapidly and to produce great dyspnœa; the skin also became somewhat thin and livid. Rupture of the sac being obviously impending, it was resolved to try galvano-puncture. Four needles were inserted parallel to each other and about an inch apart, and I applied the current of from ten to twenty-five cells of Smee's battery, so that the positive and negative pole were alternately in contact with each needle, the changes being made every five minutes, so that the whole process lasted twenty-five minutes. The patient complained much of pain, particularly when the changes were made. Arterial blood jetted freely from the punctures as the needles were withdrawn, but the hæmorrhage was at once checked by pressure. For the first two days the tumour decreased considerably in size, but afterwards it increased both in size and pulsation; redness and œdema extended around it in all directions, and the patient died on January 10, at 9 A.M. On the previous night, seeing that the skin was whitish and soft, and apprehending that the tumour might be suppurating, Mr. Holmes punctured it deeply with a thin knife. A little froth of blood and a gush of air alone issued from the puncture. At the autopsy the whole of the cellular tissue around the tumour was found loaded with lymph and much indurated. This diffuse inflammation extended the whole way up the neck, rendering the dissection extremely difficult. The aneurismal sac involved the whole of the innominate artery, and opened into the aorta by a very large orifice. It was almost filled with blood-coagula, which were firmly adherent to the sac, but had not assumed any regular concentric lamination. The aorta was greatly dilated and very atheromatous. The heart was healthy.

This was a most unfavourable case for treatment, as the patient was so reduced in strength that he must have died from exhaus-

tion or hæmorrhage in a short time. Perhaps, however, a more gentle application of the galvanic current would not have been followed by the inflammation from which the poor man ultimately sank. The result of this case has deeply impressed upon my mind *the importance of using a very gentle current in the first instance, and then watching the effect.* It is easy, if no result is obtained, to increase the galvanic power subsequently, and patients appear better able to bear a considerable power if they have been gradually accustomed to the influence by preceding slighter applications.

The second case in which I used the current, was under the care of Mr. Pick, in St. George's Hospital. As the first case had done badly under the influence of both poles in the sac, I determined in the second to use only the negative pole for the aneurism, and to close the circuit by putting a moistened sponge-conductor connected with the positive pole outside on the chest. This was a traumatic aneurism of the ulnar artery. Two needles were made to perforate the sac completely from side to side, and connected with the negative pole of the battery, the stream being kept up about twenty minutes. The application was unsuccessful. Some little bleeding followed the withdrawal of the needles, which was easily controlled by pressure; but on the following day the patient complained of much pain, and the day after the summit of the sac gave way. The artery was then tied above and below, and the man recovered rapidly.

The third case was that of an aneurism of the arch of aorta, in a gentleman aged 48, whom I saw in consultation with Mr. Elias, of Southport. In this case there was extensive heart disease, which rendered any permanent beneficial result in the highest degree improbable. I used both poles internally on one occasion only. There was no local reaction, and the patient appeared to improve both locally and generally, for the first six weeks after the operation. A relapse then occurred, and he ultimately sank from the effects of the heart disease, in April 1873.

The fourth case in which I used the current was that of a large aortic aneurism, arising very near the heart, and perforating the thoracic parietes on the right side low down. The patient was under the care of Mr. Holmes [1] and Dr. Ballard, of Southwick Place. 'In this case at first the cathode was used internally, without any perceptible effect. Both poles were sub-

[1] Holmes, loc. cit.

sequently introduced into the interior of the sac, a nodule of the tumour having approached so near to the skin as to threaten the speedy rupture of the aneurism. The effect was very striking, but only transitory. We left the man with diminished pulsation, and some solidification of the tumour. Soon afterwards the tumour ceased altogether to pulsate. This fact was not observed by any of us, but rests on the man's own testimony and that of his wife. As, however, they were intelligent people, and he had been tortured day and night for a year by the beating of a great tumour, he could hardly be mistaken on such a point. Soon, however, the pulsation recurred, and when we saw it again it was not much diminished. Still he was somewhat better, and the relief to breathing and cough, from which he had suffered severely since the commencement of the treatment, was of itself sufficient to compensate him for the very trifling inconvenience which he had experienced from the galvanism. The patient ultimately died from external hæmorrhage occurring through one of the needle-holes. His life was decidedly prolonged by the treatment, and he himself was conscious of, and grateful for, the relief afforded to his symptoms; but the disease was evidently past all hope of radical cure at the time when the treatment was commenced.'

The fifth case of aneurism I have treated electrolytically was one which was situated just at the junction of the ascending and transverse portions of the arch of the aorta. It occurred in a patient aged 49, who was admitted under the care of Mr. Holmes, in St. George's Hospital, in March last, and who died June 17. Several modes of applying the current were adopted in this case, and it was found that *only when both poles were in the sac* a decided change for the better took place. The patient being extremely sensitive to the current, he was several times placed under the influence of chloroform, but could bear the application quite well after the effects of the chloroform had passed off; so that it was not necessary to keep him very long under the influence of it. This is another fact showing the correctness of my theory *that the internal application of the constant current produces an anæsthetic effect on the parts which have for some time been subjected to its action.* The tumour in this case was situated in the right infra-clavicular region, extending from the lower border of the clavicle to the nipple, and from the mid-external line to the anterior fold of the axilla. The patient ultimately died of right pleurisy, and

it was discovered *post mortem* that the aneurism, which had corroded the cartilages of the three upper ribs and the corresponding edge of the sternum, also projected into the right pleura, in which a few ounces of turbid fluid were found, the opposed surfaces of the membrane being coated with recent lymph. The aneurism itself appeared to be in the process of healing, for its sac was filled with blood-clot, of which the circumferential part was laminated and yellow, while the central part was soft and dark-coloured.

From the results of the foregoing cases I have no doubt whatever that *the most effective application of the current is that where both poles are inserted into the sac.* This mode of application is also that one employed by Ciniselli and Dr. Duncan, of Edinburgh. Both poles are useful in different ways; the positive produces a small firm clot, and the negative a large soft one. Where only one pole is in the sac, the resistance encountered by the electricity is so great that a much larger galvanic power has to be used to produce any effect at all; and even then the effect of that pole which remains outside is lost.

A natural apprehension has been felt by many physicians whether a portion of the clot might not become disengaged, and block up a cerebral artery? Experience shows that such an accident is not likely to occur. Another fear has been that the gas which is developed in the aneurismal sac by the electrolytic process, might prove dangerous; but this likewise has turned out to be a groundless apprehension, probably because the gas is intimately mixed with liquid, and moreover appears in excessively small bubbles, some of which have only a diameter of 0·005 millimètre. It cannot therefore have the same effect as a few large bubbles of air suddenly entering a vein.

It appears to be best to protect the textures perforated by the needles from the action of the current by an insulating layer, in order to prevent sloughing or cellulitis. The difficulty of insulating the needles is considerable. Sealing-wax is totally useless, as it becomes semi-liquid at the temperature of the body, and is, as it were, peeled off from the needle by the skin, at the moment of introduction. Drs. Duncan and Fraser[1] have, however, constructed a needle insulated with vulcanite, which answers very well.

The pain of galvano-puncture is very great, if a powerful current be used at once. If the application be gentle, the inconve-

[1] Edinburgh Medical Journal, 1868, p. 115.

nience to the patient is slight, and it is as a rule not necessary to place him under the influence of chloroform. When it is, however, found necessary to use a strong current, it is better to resort to anæsthesia, which need not be kept up very long; for the current seems gradually to benumb the parts after they have been under its influence for some time. This effect was very marked in my fifth case which I treated with Mr. Holmes, where the patient, who had at first complained very much of a current of moderate power, was chloroformed, and awoke from the anæsthesia while a powerful current was passing through his aorta. He was perfectly conscious, and I asked him repeatedly whether he felt any pain, as I should have wished him to have more chloroform then; but he answered that he had no pain at all, and the current passed for another half hour without causing him any inconvenience.

How long should the application be continued? I think that the first application should not last longer than twenty minutes; and we must afterwards act according to circumstances. Where short applications have little or no effect, we must gradually prolong the action of the current to an hour, or even more. As the electrolytic effect on the skin is neutralised by the insulation of the needles used, no unpleasant effects are likely to ensue in the neighbourhood of the sac.

Dr. Duncan[1] considers that electrolysis may be hopefully used in aneurism of the great vessels, such as the aorta, innominate and subclavian arteries, if progressing in spite of proper medical treatment. He prefers compression, where this is possible, to electrolysis; thinks the latter preferable to ligature; recommends electrolysis more particularly for cirsoid aneurism, and also for varicose aneurism, gluteal and sciatic aneurism, while he believes that in many aneurisms of small arteries it is likely to prove a useful addition to our means of cure.

'For cirsoid aneurism (Dr. Duncan says) electrolysis seems to be the safest, simplest, and most certain method of treatment. Ligature of large arteries, like the carotid, is extremely dangerous, and has been singularly unsuccessful. Out of eighteen cases seven died and only two were permanently cured. The perchloride of iron, though it has been successfully injected, is also liable to failure, and has, moreover, certain well-known risks attending it. Extirpation, ligature and incision, have been tried,

[1] The Surgical Applications of Electricity. Edinburgh, 1873.

but hold out little inducement to repeat them. Galvanism, however, has been successful in the only two cases in which it has been used, and though several operations were required in each, not the slightest accident happened in either.' He has treated such an aneurism on the left side of the head of a labourer, aged 21, having the shape and size of the half of a large Jersey pear, and which was cured by four applications. Both poles were put into the sac, the application lasted for twenty minutes each time, and was made with four cells of Bunsen's battery. Each operation produced a hard core in the tumour, whereby the latter was gradually obliterated.

Meyer [1] has given the details of a case of a male patient, aged 52, who suffered from an aneurisma racemosum of the left knee, which had gradually come on after an accident; there was distinct pulsation at different points of the patella, and the temperature was considerably increased. He introduced three needles, connected with the positive pole of the battery, into those places where pulsation was most marked, while the negative conductor was applied to the thigh. Twenty cells were used, and the needles left in the tumour for fifteen minutes. The operation was nearly painless, and no bleeding took place when the needles were removed. A digital compression of the femoral artery was then resorted to for twenty-four hours after the operation, and galvano-puncture repeated four times more at intervals of six or eight days, compression being again resorted to after each application. The pulsation in the tumour gradually diminished, and the clots in the interior of the tumour became so hard that at last it was found extremely difficult to introduce the needles. A small abscess of the cellular tissue was formed at the lower portion of the patella, which had to be opened, but which healed within a week. The tumour shrank very considerably, and only a small portion remained.

Ciniselli [2] has recorded a case of aneurism of the descending aorta cured by galvano-puncture. The patient, aged 46, had a round pulsating tumour on the right side of the sternum, in the third intercostal space; it was six centimètres wide and almost equally long, and was elevated about one-and-a-half centimètre above the level of the walls of the thorax. Ciniselli believed it to be an aneurism of the lateral portion of the aorta descendens

[1] Loc. cit. p. 45.

[2] Gazette des Hôpitaux, 1868, No. 134.

thoracica, and used for its cure three steel needles one millimètre thick, which were introduced into the third intercostal space, one being about two centimètres distant from the other. The positive pole was first connected with one of the needles, and the negative with a spongeholder applied to the skin in the neighbourhood of the tumour. He then connected the positive pole with the second needle, and the negative with the first, where the positive pole had already acted, &c., until each needle had been in contact with both poles. The application lasted forty minutes; the skin had become reddened and swollen. After a few days these local symptoms abated; there was no general reaction. Sixty-six days after the operation the patient was completely cured.

Ciniselli[1] thinks that in most cases, where the electrolytic operation fails, this is due to the circumstance that some of the great arteries which spring from the arch of the aorta take their origin from the aneurismal sac itself; and the too rapid passage of the blood into the sac impedes the formation of the electrolytic clot. He has lately treated four cases of introthoracic aneurism unsuccessfully, and lays it down as a principle that, when a great arterial trunk takes its origin from the aneurismal sac, the operation is useless.

One of these latter cases of Ciniselli's is the following, which was diagnosed as that of an aneurism of the end of the arch of the aorta:—The patient had suffered intensely for eighteen months. On May 29, 1871, Ciniselli introduced three steel needles one millimètre thick, into the middle of the first left intercostal space, about 4 centimètres deep, the needles being at 2 centimètres distance from one another, the internal one being one centimètre from the edge of the sternum. Considerable vibration was at once communicated to the needles, which described an oscillating movement from above downwards. All the needles were successively connected with the negative and positive poles, the changes being made not according to time, but whenever the characteristic phenomena of the electrochemical action appeared—that is to say, a black circle round the positive, and a pallid zone round the negative pole. The whole electric action occupied thirty-five minutes. After the operation, the pulsation and vibration were less. There were no bad symptoms, and the patient recovered sufficiently to be able, two

[1] Il Galvani, Jan. 1873.

months afterwards, to return to his business as carman. If he took things easily he could do his work well; but working hard, or any excesses in diet, made him much worse. He suddenly expired on September 24, after having done some particularly hard work, about four months after the operation. No necropsy could be made.

Dr. McCall Anderson[1] has been successful in a case of aneurism of the thoracic aorta, in which he used Stöhrer's battery, and a needle insulated to within half an inch of its point, by being coated, as recommended by Dr. Duncan, with a mixture of shellac and gutta percha. The operations where performed thus:—The skin at the edge of the aneurismal swelling having been frozen with ether by the aid of Dr. Richardson's spray-producing apparatus, the needle connected with the positive pole was passed obliquely into the aneurismal sac. A zinc plate, connected with the negative pole, was then applied to the chest-wall on the opposite side and about three inches beyond the edge of the swelling, a sponge wrung out of warm salt water intervening between the plate and the skin. The cells of the battery were then raised in the usual way, and the sledge pushed up so as to bring four, six, or eight cells into use. When the process was completed the sledge was slowly pushed back, the zinc plate removed from the skin, and the needle extracted, a piece of plaster being applied over the puncture.

The patient was a woman aged 46, who, two years and a half ago, began to complain of a 'violent beating at her breast' and of hoarseness. About four months after the onset of the palpitation she first experienced a sensation as if a heavy weight were pressing upon her chest, and complained of lancinating pains between the shoulders, which extended down the left arm, and which gradually increased in severity. About eighteen months previous to admission she observed a swelling in front of the chest, which was then about the size of a small hen's egg; it extended gradually at first, but more rapidly during the last six months of this time. From the time of appearance of the tumour the palpitation became more marked, being also aggravated by movement; and dyspnœa set in, so as to prevent her from lying with any degree of comfort save on her left side.

On inspection of the chest the swelling was seen at the lower and inner part of the left infra-clavicular space and implicating

[1] The Lancet, May 1873.

also the upper sternal region. It was about three inches and a half in diameter, and its apex—for it was somewhat conical—was about an inch and a half above the surface. Pulsation and expansion could be distinctly seen and felt, and palpitation elicited well-marked purring tremor over it. A well-marked systolic murmur was audible, and the left ventricle was the seat of hypertrophy and dilatation.

Treatment by ice locally and by iodide of potassium internally having proved ineffectual, electrolysis was resorted to on April 4, and continued for half an hour, four cells being employed for the first quarter of an hour, six for the second. Two days afterwards the swelling was found to be firmer, and she could take a deep inspiration almost without any pain. On April 9 galvano-puncture was employed for the second time, and was unattended by hæmorrhage or complication of any kind. On April 26 the tumour was decidedly smaller, and for the most part firm and solid. It still pulsated however; and the systolic murmur, though not nearly so pronounced, was still present. The operation was therefore repeated, the needle being passed into the soft part of the swelling. This produced marked improvement; the tumour became firmer at the lower part, diminished in size, and the pulsation became less distinct. On August 27 galvano-puncture was again made use of, six cells being employed for the first quarter of an hour, eight for the following five minutes, and six for the last ten minutes. The battery, having been recently reamalgamated, acted more powerfully than formerly, so much so that when eight cells were used she complained of decided uneasiness. The result of this operation was, that the swelling was further reduced in size and rendered firmer. On October 26 the tumour was only about one quarter of its size before galvano-puncture was resorted to, and was for the most part very solid, much more so than the surrounding healthy parts of the chest. There was no trace of purring tremor, and its pulsation was much diminished. The patient felt in perfect health, and her only complaint was of a feeling of pulsation within the chest.

Dr. Brandis, of Aix-la-Chapelle, has cured by electrolysis a large femoral aneurism close beneath Poupart's ligament, in a man aged 33. The tumour was 22 centimètres broad, and 18 centimètres long, and had first appeared six years before, without known cause. It had increased rapidly during the last few months, and the patient now suffered so much pain as to be unable to work. It was very difficult to distinguish the femoral

artery above the aneurism. There was nothing wrong with the heart or the rest of the arterial system. Digital and instrumental pressure, as well as forcible flection of the hip-joint, were tried unsuccessfully, the patient being unable to endure the restraint for more than ten minutes at a time. The operation was made with 30 cells of Stöhrer's battery. Platinum needles were used, whose extremities were exposed for three centimètres only, the rest being covered with shellac. The external iliac artery was compressed, and the needles were then introduced into the tumour for a depth of five centimètres (two inches), and four centimètres apart. The needles were kept in for six minutes, within which time a dark area of blistered skin formed round the point of introduction of the positive pole. The current was now reversed, and the same thing occurred round the other needle. In fact the shellac had melted, and did not protect the superficial tissues. An eschar had formed around each needle puncture three-fourths of a centimètre broad. The needles were now put into other parts of the aneurism, and the current made to act altogether for thirty-five minutes.

By that time, a large quantity of gas had been set free in the sac, so that the aneurism had become plainly tympanitic, and for a hand's-breadth the skin was emphysematous. Hard masses might be felt in the aneurism. The compression of the artery was continued for two hours and three-quarters, during which period the aneurism distinctly hardened, and when the pad of the compressor was raised sufficiently to allow pulsation to be felt in the femoral, no thrill was perceived in the tumour. Four hours after the commencement of the operation, all compression was removed, and the patient allowed to recover from the effects of chloroform. No pulsation could be felt in the tumour, which had diminished in width three centimètres, and in length two centimètres. The femoral could be felt pulsating down to the tumour, but below this no pulsation could be felt anywhere. Pulsation never returned in the tumour, which gradually diminished in size and became harder. Two smart attacks of fever occurred, however, the first through the suppuration of the needle-tracks, the second through the formation of an abscess beneath the fascia lata on the outer side of the thigh.

Six weeks after the operation the patient got up for the first time, and was discharged cured at the end of January; nothing was then left of the tumour except a small hard lump.

Before the chemical properties of the different forms of electricity were well known, faradism has occasionally been used for the cure of aneurism, as it was thought electricity was one and the same thing under all circumstances. Such a case has been recorded by Mr. Eyre.[1] There was a pulsating tumour in the left groin, of the size of a fowl's-egg; the pulsation was very strong, and accompanied with a bruit which could be traced two inches above the tumour; the limb was swollen and painful. Needles connected with the poles of an induction apparatus were introduced into the sac, and a current sent through it for some time. Alarming signs of inflammation supervened, and it was not until seventeen days after the operation that the tumour felt harder, and the pulsation became fainter. In this case electricity acted merely as a stimulant, and the sac was closed in consequence of irritation and adhesive inflammation, but not by chemical action. It is hardly necessary to state that the employment of induction currents for the cure of aneurisms is not justifiable.

Varicose viens and *varicocele* may be electrolysed in the same manner as aneurism; but the results of this treatment appear generally not to be of a permanent character.

XVIII.—DISEASES OF THE URINARY ORGANS.

Stricture of the Urethra was first galvanically treated by Crussel and Wertheimber, but to Messrs. Mallez and Tripier[2] the merit is due of having proposed an intelligible method of applying the constant current. They recommend electrolysing the stricture by introducing a urethral electrode which consists of a wire covered with an elastic catheter, the anterior portion of which has been cut off in order to protect the surrounding parts from cauterisation. This is put to the seat of the obstruction, and connected with the negative pole of twelve pairs of the bisulphate of mercury battery; the positive electrode is a moistened sponge-conductor, fixed on the inner surface of the left thigh. As soon as the circuit is closed, the patient feels a slight pricking sensation, which, however, diminishes in proportion as the eschar is formed. The metallic point is then pushed forward, so as to cauterise the different parts of the stricture; and when the impediment is

[1] The Lancet, July 1853.

[2] De la guérison durable des rétrécissements de l'urèthre par la galvano-caustique chimique. Paris, 1867. 2nd edition, 1870.

destroyed, the sound is pushed forward beyond the point of the wire. A catheter can then be easily introduced into the bladder, showing that the stricture has been overcome. Messrs. Mallez and Tripier have treated thirty-one cases by this method in a public dispensary, with satisfactory results. It is true that one of these patients died a week after the operation, of urethral fever; but he had already once before nearly died of that after urethrotomy. The authors of the operation do not consider that their proceeding should be made responsible for this fatal result, as death has occasionally occurred after simple catheterism, in persons who were either in bad general health, or suffered from disease of the kidneys. In the patient alluded to, the immediate effects of the operation had been satisfactory. One operation is generally sufficient, and nothing further need be done; but the catheter is introduced from time to time, in order to see whether the result of the treatment has been permanent. They say that the size of the urethral canal, instead of diminishing, increases for a week or two after the operation, and consider this due to the absorption of peri-urethral effusions, which have been brought under the influence of the negative pole. The following is one of Mallez and Tripier's cases:—

A custom-house officer, aged 62, had had gonorrhœa at the age of twenty, and passed his urine with difficulty for the last ten years. For the last eighteen months there had been incontinence, which obliged the patient to wear a urinal. He was unable to follow his employment. On May 2, 1864, the urethra was explored with an elastic bougie, which encountered an obstacle at the end of the spongy portion of the urethra; and rectal examination showed the existence of hypertrophied prostrate without deformity. For twenty minutes it was tried to introduce a bougie No. 3 into the bladder, which caused a few drops of blood to appear. On May 6 a bougie No. 3 was introduced after patient trials of three-quarters of an hour; and on May 9 the stricture was electrolysed to the extent of half an inch. The application lasted five minutes: immediately after the operation, bougies No. 19 and 20 could be introduced without any difficulty, and the patient passed his water in a full stream. No fever supervened. The incontinence ceased, and he was no longer obliged to wear the urinal. He was seen several months afterwards, when he was in excellent health, and there was no return of the stricture.

In most cases operated upon by Messrs. Mallez and Tripier, one application of the current appears to have been sufficient for the cure of the stricture; in a few others from two to five were necessary. In only one case did the patient complain of pain during the operation, and in a few only was there slight hæmorrhage afterwards. Some of these cases have remained under observation for more than three years, without a relapse having taken place.

Prof. Dittel,[1] of Vienna, does not share the sanguine expectations of Tripier and Mallez. He has used electrolysis in three cases of stricture without any result. In one case there was a rise of temperature and acceleration of the pulse in the evening of the day when the current had been used; and in another local urethritis ensued; in none of the three, however, was it possible to advance the catheter the least bit after the operation. I must, however draw attention to the circumstance that Prof. Dittel appears, according to his own description, to have used the reverse position of the poles recommended by Tripier. The latter uses the negative pole for the stricture, and the positive for closing the circuit; while Dittel says that he used the positive for the stricture, and the negative outside. This of course would render his experiments useless as far as they would control Tripier's. *The use of the positive electrode for the urethra I should consider, under any circumstances, one of the greatest electro-therapeutical mistakes which could be made*, as it is almost certain to cause inflammation; and even the removal of the electrode from the urethra cannot be effected without violence as it becomes firmly glued to the mucous membrane. A prolonged and powerful action of the positive electrode in the urethra would probably cause a stricture.

Paralysis of the bladder is a term which has been somewhat loosely applied to cases in which there is difficult micturition, but where the bladder is not really paralysed. Patients in whom this organ has lost its function of acting as a reservoir for the accumulated urine, are said to suffer from incontinence, or paralysis of the sphincter of the bladder; and again, cases in which some mechanical obstruction, such as hypertrophied prostate, offers an impediment to the discharge of the urine, are

[1] Handbuch der Chirurgie von Pitha und Billroth. Erlangen, 1873. Vol. iii. p. 572.

frequently put down as paralysis of the bladder. Strictly speaking we can only speak of paralysis of the bladder—that is to say, inability to pass urine in the natural way from loss of motor nervous influence :—

1. When the conduction of nervous influence from the *pedunculus cerebri* to the bladder is interrupted. This occurs in certain cerebral diseases, in hysteria, in typhoid fever.

2. When the influence of the *lumbar portion of the spinal cord* is removed, as in chronic myelitis, certain injuries of the spine, and in atony of the cord. The inability to pass urine is here due partly to paralysis of the motor nerves of the bladder, and partly to an increased reflectory tone of the urethral muscles, which close up the orifice of the bladder and do not allow the urine to escape.

3. When the normal excitability of the *motor or sentient nerves of the bladder* is pathologically altered, without any central affection being present. Most cases of this kind originate in affections of the sentient, not of the motor, nerves of the bladder, and should therefore be looked upon as instances of reflex or inhibitory paralysis. This occurs after instrumental interference—such as the operation of lithotrity; after any operations for piles, but chiefly where the actual cautery is used; and after childbirth, owing to the pressure of the head on its passage through the pelvis. Local paralysis of the bladder is also observed after the use of certain drugs which have a special influence upon the nerves of the viscus, such as belladonna and hyoscyamus.

It will be observed that I do not include under the heading of ' paralysis of the bladder ' cases of *atony* of the viscus from overdistension. The pathology of such cases is quite different. They occur either in consequence of some organic obstruction—such as stricture or hypertrophied prostrate, preventing the complete emptying of the bladder; or in people who, on a single occasion, or habitually, for some reason or another, suppress the desire to pass urine. In such cases, the muscular fibres of the bladder become overstretched and lose their tone, but there is not necessarily any failure of nervous power combined with this; and it is, therefore, preferable to avoid the term ' paralysis ' for cases of this kind.

The treatment of paralysis of the bladder has hitherto, on the whole, been unsatisfactory, more especially that of the first two forms of the disease, where the affection is owing to cerebral or

spinal mischief. The remedies most usually recommended and employed are strychnia, ergot of rye, cantharides, arsenic, iron, and faradisation. These remedies have, no doubt, succeeded in curing or improving a number of cases, more especially of the third class; but they have, to my personal knowledge, often remained ineffectual even in such patients, and rarely, if ever, do any good in the cerebral and spinal varieties of the disease. It is especially well known of faradisation, that it has little or no therapeutic influence in diseases of the nervous centres; and, if employed at all in paralysis of the bladder, it should only be used in the local and reflex or inhibitory form of the disease. Under these circumstances it is certainly a matter of congratulation that we possess in the constant galvanic current a remedy which, if properly applied, appears always to be able to restore the influence of volition over the bladder, unless actual destruction of the nervous matter involved should have taken place. From what I have seen of its effects in a number of, at first sight, unpromising cases, I have no hesitation in asserting that, both in efficacy and quickness of action, it is infinitely superior to all other remedies which are generally used for this affection; and that, where there is a physiological possibility of restoring the voluntary action of the viscus, we shall be able to effect it by the aid of the constant current.

The mode of using this agent is of considerable importance. Experience has shown me that it is neither necessary nor expedient to apply the current directly to the tissue of the bladder itself, as we might do by means of an insulated sound, with a free metallic knob, introduced into that organ. Direct galvanisation of the full bladder is objectionable, because a powerful chemical decomposition of the urine is the consequence of such a proceeding, giving rise to symptoms of fainting, owing to the sudden distension of the viscus by the gases which are set free; while direct galvanisation of the empty bladder appears to produce an irritating effect upon its mucous membrane. External galvanisation produces none of these inconveniences, and is thoroughly effective, so that it should in all cases be employed in lieu of direct internal galvanisation.

The position of the electrodes should vary according to the seat of the affection. Where we have reason to believe that it is due to disease involving the pedunculus cerebri, one director connected with the negative pole should be placed to the back of

the head, and another connected with the positive pole above the os pubis. The latter electrode should have a large surface. In cases of disease of the lumbar portion of the spinal cord, the negative pole is placed to the lower part of the lumbar spine, and the positive in the same position as above. Finally, in local paralysis of the bladder, we may either use the same arrangement of the electrodes as in spinal disease, or both directors may be placed above the os pubis.

How long should the application of the current be continued? and should it be intermittent or continuative? The intermittent application, according to my experience, is far superior to the continuative—a fact which is in perfect consonance with the results obtained by the same method in other forms of paralysis. Fifty or sixty intermittences of the current are sufficient for one application. I am in the habit of leaving the positive pole *in situ*, and of removing the negative every three or four seconds, putting it on again immediately afterwards. The whole time of application in such cases, therefore, does not exceed three or four minutes.

The current used must have a certain tension; for, if it be feeble, no result is produced. I have in most cases used fifty or sixty cells of Daniell's or Smee's battery; but, in the cerebral form of the disease, less power may be employed.

I now proceed to narrate a few cases illustrative of the different varieties of paralysis of the bladder, and their treatment by the constant current.

CASE 64.—*Hysterical Paralysis of the Bladder.*—A married lady, aged 32, of highly nervous constitution, who had lived much in the tropics, was sent to me by Dr. Frank in July 1870. She had been very delicate as a child, and her mother had died of phthisis. Family troubles thoroughly upset a system naturally predisposed to nervous disturbances, and in which only some powerful exciting cause was required for the full development of hysteria. Early in 1870, when she was under the care of Dr. Siordet, of Mentone, the patient had cataleptiform seizures, and convulsive attacks resembling opisthotonus. She soon after lost her voice, and the power of walking and of voiding the urine. From March 6th, until the time she came under my care, the catheter had to be introduced twice daily. This was a cause of great annoyance, for it became necessary that the patient should, even in her travels, merely on account of this symptom,

be constantly accompanied by a medical man able to give relief to the bladder. The urine in this case was quite normal.

Galvanisation of the cervical sympathetic and the spinal cord was resorted to in this patient for producing a beneficial modification of the constitution of the nervous system. A current of fifty cells was also applied to the bladder on two several occasions (July 30 and 31). After the first such application, the patient passed her urine in a feeble stream, and with a certain amount of pain and straining; after the second application she could pass it freely, and had fully retained the power of doing so when I last heard of her, ten months later (May 1871).

CASE 65.—*Paralysis of the Bladder from Disease of the Lumbar Portion of the Spinal Cord.*—A gentleman, aged 46, married, of spare habit, and without regular occupation, was in his usual health in Summer 1870, when he went for change of air to Blankenberghe, near Ostend. He took a most active part in all the gaieties which were going on there, and, amongst other things danced all the dances every night at the casino, which he had not done for many years past. After this kind of life had gone on for about a month, he suddenly lost the power over the bladder, being altogether unable to void his urine, so that the use of the catheter became necessary. Soon after he also lost to a great extent the power over the lower extremities, so that he was unable to walk for more than a few minutes at a time; and he began to suffer from obstinate constipation. Symptoms of catarrh of the bladder now likewise made their appearance. The patient consulted a number of eminent physicians and surgeons, both in Germany and England, who treated him with iron, nux vomica, arsenic, ergot of rye, and various other medicines, but without beneficial result; and he came under my care in March 1871.

The symptoms had, on the whole, not varied much since their first appearance, but the catarrh of the bladder was now rather worse than before. The specific gravity of the urine was 1·025; it had a very feebly acid reaction, and readily turned ammoniacal on standing; it contained a large quantity of muco-pus. There were occasional attacks of great irritability of the bladder, attended with chilliness, chiefly at night. He introduced the catheter three times daily, and when the bladder was irritable, as many as six times; and he never passed his urine in the natural way. Digestion was impaired, flatulency complained of, and the action of the bowels was sluggish and uncomfortable. The

patient was in a most desponding state of mind, and almost despaired of recovery. He was treated with galvanisation of the lumbar spine, and of the bladder. After the second application he could pass his urine freely by himself, and only introduced the catheter at bedtime, in order to make sure that the bladder was completely emptied. At first he generally found about eight ounces of urine in the bladder; but, as the treatment proceeded, the quantity drawn off at night became reduced to two or three ounces, showing that the expulsive power of the viscus became more and more strengthened. The patient likewise underwent medicinal treatment for the catarrh of the bladder, and peripheral galvanisation was used for the lower extremities and the rectum: but it would be foreign to my purpose to enter at length into these matters. Suffice it to say that, when he discontinued the treatment in June last, the expulsive power of the bladder was all that could be desired; that the action of the bowels was much easier, and that he could walk some miles at a time without fatigue. The urine still contained muco-pus, but not nearly as much as before, and its reaction was now strongly acid.

Mr. Taylor,[1] of Anerley, has recorded a case of paralysis of the female bladder after forceps delivery, and in which the ordinary remedies had been used without any effect. He then introduced an insulated electrode into the bladder after the organ had been emptied, and applied faradisation. As two such applications, however, produced only little effect, he next faradised the full bladder, when, under the influence of the electric current, the organ forced the urine out by the side of the instrument, and on the same day the patient was able to pass urine voluntarily. Faradisation was repeated once more, after which the patient had regained the full control over the bladder.

In *atony of the bladder* from over-distension, faradisation of the full bladder by a single vesical electrode is probably the most successful treatment.

Galvanic dissolution of urinary calculi has been proposed as far back as 1801 by M. Bouvier de Mortier. In 1803, Mongiardini and Lando, and in 1813 Gruithuisen again recommended it for such purposes, but it was only in 1823 that the first successful experiments on this subject were made, by Messrs. Prévost and Dumas.[2] They determined to destroy the state of

[1] The Lancet. Vol. i. February 1868.

[2] Annales de Chimie et de Physique. Paris, 1823. Vol. xxiii. p. 202.

aggregation by which the molecules of the calculus are bound together; for they argued that, if once it was made friable, it would easily pass out. They did not therefore, subject the calculus to direct chemical dissolution, but utilised the mechanical action of torrents of gases in order to alter its texture, and reduce it to a fine powder. They first submitted a fusible human calculus to the action of a voltaic pile of 120 pairs, for twelve hours consecutively. The pile was recharged every hour. Platinum wires serving as electrodes were placed at two opposite points of the calculus, which was immersed in a vessel filled with water. After a time a fine powder was precipitated. At the commencement of the experiment the calculus weighed 92 grains, and at the end of it only 80. After having been subjected once more to the action of the pile for sixteen hours, the calculus became so friable that the slightest pressure reduced it to small crystalline grains; the largest fragments were scarcely the size of a lentil, and the canal of the urethra would not therefore have opposed their exit. Prévost and Dumas made a similar experiment on a living bitch. A fusible calculus fixed upon a sound was introduced into the bladder of the animal, and the electrodes so arranged that they touched the calculus on opposite points. Warm water having been injected into the bladder, the electrodes were connected with the poles of the pile. The calculus was left for an hour in this state, and when taken out showed unequivocal signs of decomposition. The same process was repeated every morning and evening for an hour each time, on six successive days; after which the stone was so friable that the experiment could not be continued. A few days afterwards the bitch was killed and the bladder examined; it was then observed that its tissue had in no way been injured by the operation.(?) No human being could possibly undergo what this poor bitch underwent, without being killed by the effects of the inflammation which must necessarily follow such a proceeding.

In 1835 M. Bonnet, of Lyons,[1] succeeded in dissolving calculi by the chemical action of the voltaic pile. He placed different calculi between platinum electrodes immersed in a solution of a drachm of nitrate of potash in four ounces of water, and dissolved them by directing a continuous current to their texture. Stones of oxalatate of lime were the only ones which resisted the action of the current, while calculi of every other description were dis-

[1] Bibliothèque universelle de Genève, 1835. Vol. lviii. p. 391.

solved more or less rapidly. The point which M. Bonnet thinks he has established is, that we may convey to the stone acids and alkalies, merely by the electro-chemical decomposition of a saline solution, without these powerful substances being diffused in the urine contained in the bladder. Most urinary calculi may be dissolved either by nitric acid or by potash; but these substances cannot be introduced into the bladder without cauterising its tissue. If, however, a solution of a neutral salt, such as nitre, be injected into the bladder containing the calculus, and the electrodes connected with the poles of the pile are made to touch opposite surfaces of the stone, M. Bonnet argues that the solution of nitre is decomposed, nitric acid being attracted in very small quantities to the positive pole, and potash to the negative pole. One of the sides of the calculus would therefore be subjected to the action of nitric acid, and the other to that of caustic potash. A stone composed of phosphates would be dissolved on the acid side, and one consisting of uric acid, or urate of ammonia, on the alkaline side. But while this process of dissolution is going on, the calculus and the mucous membrane of the bladder would be in contact with the neutral solution. Such reasoning is evidently that of a special pleader, because if a calculus of uric acid were to neutralise all the free potash, what would become of the nitric acid? It is evident that this would accumulate in constantly increasing quantities as the action of the current went on, and would do fearful mischief to the tissues of the bladder. M. Bonnet has evidently not seen this, but argues that if the action of the current be kept up, the electrode would gradually penetrate to the interior of the stone, but always on one side only. In this way stones of phosphate of ammonia and magnesia, phosphate of lime, ammonia, and magnesia, urate of ammonia and uric acid, would be dissolved. If the texture of the stone be very dense, the solution would be confined to the point touched by the electrode, but if the stone be formed of layers which are only feebly connected with each other (as is the case with such of urate of ammonia, and triple phosphates), or if it be porous, when formed of phosphate of ammonia and magnesia, the calculus would soon become friable, and the layers separated from each other. The dissolved part would not remain in solution in the liquid, but be precipitated in the bladder as a fine powder of subphosphate, or of uric acid.

In the course of his experiments, M. Bonnet several times

changed the saline solution in which the calculi were immersed, using the phosphate, the hydrochlorate, and the borate of soda, and the fluate of potash, instead of nitre; but he found that none of these salts had such a general and powerful action as the nitrate of potash.

Similar experiments were made in 1853, by Dr. Bence Jones,[1] who confirmed nearly all the results previously obtained by M. Bonnet, and found that calculi of oxalate of lime, which had been pronounced indissoluble by M. Bonnet, could be dissolved, although only slowly.

The only author who affirms having dissolved calculi in the human bladder by galvanism, is Dr. Melicher,[2] of Vienna. But as he has not described the instruments used, nor given his cases in full detail, his statements are devoid of value.

The mechanical effect of electric discharges has also been recommended for disintegrating calculi. It is well known that electricity of high tension is able to destroy the molecular structure of imperfect conductors; thus lightning will break and pulverise stones, panes of glass, and other similar bodies which it cannot traverse without destroying them. Proceeding from these facts Mr. Robinson has endeavoured to reduce stones to a fine powder by discharging a Leyden jar through them, and has succeeded in pulverising phosphatic, mulberry, and lithic acid calculi, which were previously placed in a bladder or in vessels of glass or earthenware filled with water. No effect was produced if the surrounding medium was air. He recommends the introduction of two conducting wires by means of an elastic catheter into the bladder, the wires being connected separately with the inner and the outer coating of the jar, and their free extremities being separated in order to grasp the stone. The consequences may be imagined. It is hardly necessary to say that electricity or galvanism will never supersede lithotrity for the treatment of small stones, nor lithotomy for that of large ones.

XIX.—DISEASES OF THE MALE ORGANS OF GENERATION.

Impotency has often been electrically treated. Dr. Westring,[3] a Swedish physician, has recorded the case of a man, aged 36,

[1] Philosoph. Transactions, 1853, p. 201.

[2] Oesterreichische medicinische Jahrbücher, 1841, p. 153.

[3] Journal du galvanisme et de la vaccine, 1803. Vol. i. p. 297.

who had become impotent in consequence of debauchery; erection was imperfect, ejaculation took place too quickly, and without any pleasurable sensation. The patient was treated with the continuous current applied by means of metallic conductors, and had within a fortnight quite regained his virile power. M. Stacquez[1] cured a case of impotency by shocks from a Leyden jar; his patient was an officer, aged 35, who had been impotent for several years. M. Duchenne[2] has been successful with faradisation of the testicles and spermatic cord; and M. Schultz[3] and M. Roubaud[4] have likewise seen good results from the galvanic treatment of such cases.

Want of erectile power is a frequent cause of impotency, and curable by electricity, unless it is caused by malformation or other serious pathological changes in the male organ. In such cases faradisation of the ischio-cavernosus and bulbo-cavernosus muscles, which preside over erection, is useful. The same application may be resorted to in cases of sexual hypochondriasis, where patients, for some reason or another, imagine that they are impotent, but where virile power is not really impaired. In anæsthesia of the skin of the sexual organs, faradisation of the skin of the organs may be resorted to.

CASE 66.—In June 1858, Mr. Curling sent to me a gentleman, aged 26, who had completely lost his virile power after gonorrhœa, for the cure of which he had been advised to make caustic injections. Faradisation of the ischio-cavernosus and bulbo-cavernosus muscle, and of the penis, restored his energy in a short time. The power was subsequently lost again, but returned for good after a second course of faradisation, in August 1859.

Where impotency is caused by general malnutrition, diabetes, syphilis, lead-poisoning, or the habitual use of opium and hasheesh, excessive tea or coffee-drinking, by over-study and similar causes, a general treatment should be combined with the application of electricity. In such cases the production of cat-electrotonus of the lumbar portion of the cord, together with galvanisation of the penis and testicles is superior to faradisation. Where the virile power is lost from disease of the spinal cord, galvanisation of the cord may restore the sexual energy, without

[1] Archives belges de médecine militaire, 1849.

[2] De l'électrisation localisée, etc., p. 764.

[3] Wiener medizin. Wochenschrift, 1857, No. 10.

[4] Traité de l'impuissance et de la stérilité chez l'homme et chez la femme. Paris, 1855. Vol. ii. p. 685.

any local application to the organs themselves having been made.

Mr. Curling[1] has shown that there may be capacity for sexual intercourse, but at the same time inability to procreate, or *sterility*; and that this inability in man arises from malposition of the testicles, obstruction of the excretory ducts of the testicle, impediments to the escape of the seminal fluid, and aspermatism.

Whether deficient secretion of semen may be improved or cured by electricity is at present not known. It does not appear impossible that it should be so, for electricity has considerable effects in rousing the activity of the vaso-motor and secretory nerves in general. By electrifying the skin, we may produce erythema and papular eruptions; in cases of amenorrhœa electricity is often instrumental in restoring menstruation; in paralysed limbs which have been cold and flabby, a proper degree of animal heat may be induced by galvanisation or faradisation; a deficient secretion of cerumen may be increased, and lacteal secretion in women after parturition may be excited; and the secretion of tears, of nasal mucus, and of saliva, is likewise stimulated by the application of electricity. It therefore appears, *à priori*, not unreasonable to expect that the secretion of semen may be restored or improved by galvanising the spermatic nerves or the testicles; provided, of course, that the want of secretion is due to paralysis of the secretory nerves of these organs, and not to the results of inflammation, cancer, tubercle, or other pathological processes which destroy the texture of the testicles, and therefore render secretion impossible. Observations on this point are as yet wanting, but in the absence of other remedies for the condition just mentioned, electricity, and more especially the constant current, deserve a trial.

Spermatorrhœa may occur both during sleep and in the daytime, and is generally the consequence 'of the passions being excited without an opportunity being afforded for their gratification.'[2] In nine cases out of ten, spermatorrhœa comes on after masturbation has been practised for some time, and constitutes a very troublesome complaint, which is generally attended by symptoms pointing to a profound disturbance of the central nervous system. Mr. Curling recommends the application of

[1] A Practical Treatise on the Diseases of the Testes, and of the Spermatic Cord and Scrotum. London, 1866. Third edition, p. 433.

[2] Curling, loc. cit. p. 453.

nitrate of silver to the prostatic portion of the urethra, in those cases which do not get well by a constitutional treatment, and the occasional introduction of bougies; and his success appears to have been marked. Galvanisation of the prostatic portion of the urethra (p. 344) may likewise be employed. It has the advantage that it can be readily adapted to the special sensibility of each patient, and that it causes no distress during or after the application, if this be judiciously performed.

CASE 67.—A gentleman, aged 26, consulted me in January 1868. He had been in good health until he began to masturbate five years ago, which habit he had continued for three or four years. Within the last three years he had suffered from very frequent seminal emissions at night, in consequence of which his general health had suffered considerably; at present not a single night passed without an emission, and there were sometimes three in one night. The memory was bad, the patient felt unable to work, and complained of heaviness about the head, great despondency, and pain and weakness in the back. I prescribed mineral acids, and applied the cathode of fifteen cells for two minutes to the veru montanum by means of an insulated metallic conductor, the anode being placed to the perineum. Galvanism was afterwards applied to the parts externally, three times a week. The patient now had no emission for fifteen nights consecutively. He had one in the sixteenth night, and galvanisation of the urethra was then repeated. After this he went sixteen nights until he had another emission; and the one he had then was the last he had while he continued under my care (three months). His general health had at the same time become much better, and the despondency of mind had given place to his natural cheerfulness.

Dr. Ruschenberger, of the United States' Navy, Prof. Pétrequin and M. Scoutetten, have cured obstinate cases of *hydrocele* by galvano-puncture, both electrodes being introduced into the sac. Dr. Lehmann and M. Tripier have used farado-puncture, and have also been satisfied with the result. Dr. Friedlaender of Vienna, and Dr. H. Campbell, have successfully used the method first recommended by me, viz. to direct the negative pole only to the liquid, and to place the positive outside. Two needles and fifteen or twenty cells appear to be generally sufficient. Care should be taken that the points of the needles should project into the fluid, as, if they were merely passed into the subcu-

taneous cellular tissue, or the tunica dartos, the current would only act upon these membranes, but not upon the liquid accumulated in the sac of the tunica vaginalis.

The following is one of Dr. Campbell's cases :—

'R. M., æt. 42 years, came under treatment on November 20, 1870. He had been troubled with chronic orchitis and hydrocele on the left side for upwards of fourteen years; the former was the result of a blow, and had gone on until the testicle was now about three times its original size. The latter had been frequently emptied by tapping, and usually filled again in a few weeks. On examination the left side of the scrotum was found to offer the usual appearances of hydrocele; the testicle was pressed up against the left abdominal ring, and could be easily felt in that position. At a rough guess the sac might be estimated to contain about thirty ounces of serum. Before proceeding to electrolysis, I felt disposed to draw off some of the fluid, but on second thoughts concluded it would be better to allow it to remain, so as more fully to test the power of the electric current, and also, by the distension of the sac with its full amount of liquid, allow the whole of the secreting surfaces of the sac to be exposed to the same action.

'I accordingly introduced three gilt steel needles, each two inches long, into the sac, and connected them by means of Dr. Althaus' 'serres fines' conductor with the negative pole of a Foveaux's battery. The circuit was completed by placing the positive electrode in the groin of the same side. A power of ten cells was first used, as the patient was nervous and intolerant of pain; but this was gradually increased to twenty cells, as he became convinced it did not hurt him. The current was allowed to pass for fifteen minutes, during which time, by aid of the stethoscope, a well-marked crackling could be heard in the hydrocele, evidently marking the evolution of hydrogen, and proving that the electrolytic action of the current was going on freely.

'On withdrawing the needles no bleeding occurred, and beyond a slight puffiness no change was perceptible externally. He was seen again on the 23rd. By that time the swelling was entirely gone, the sac was quite empty, no inflammation had come on, and the œdema, which always follows acupuncture in the usual

[1] Loc. cit. p. 19.

manner, had been entirely wanting. In fact, no unpleasantness of any kind had followed the operation.

'He was seen occasionally after this, but nothing worthy of note occurred except that we could observe the left testicle was gradually lessening in size. On February 5 following, after a most careful examination, no trace of the hydrocele could be discovered. The left testicle was reduced to its normal size, and the scrotum was of the usual healthy appearance. More than a year having now elapsed without the least symptom of return, we may reasonably assume that the cure is radical. One very important conclusion may be drawn from this case—viz. that electrolysis not only decomposes the contents of a serous sac, but produces such a profound alteration in the nutrition of its secreting surfaces that no further serum is poured out. I had not anticipated any alteration in the enlarged testicle, but the absorption of the products of inflammation in its parenchyma is another noteworthy circumstance, more especially as chronic orchitis usually leads to degeneration of the substance of the gland itself. I have seen this patient as recently as December 21, 1871, and, after a most careful examination, can discover no trace of the disease.'

XX.—DISEASES OF THE FEMALE ORGANS OF GENERATION.

Electricity has been frequently employed for the cure of *amenorrhœa*, and generally with satisfactory results. Dr. Golding Bird[1] expresses his belief that it is the only really direct emmenagogue we possess, and that it always excites menstruation where the uterus is capable of performing this function. It is singular to find Dr. Wilks[2] stating just the reverse. There is, however, no doubt that every form of electricity has an almost specific stimulating influence upon the vasomotor nerves of the ovaries and the uterus. Dr. Bird has cured twenty out of twenty-four cases of amenorrhœa, by the application of static electricity. The mode in which he applied it was to transmit a dozen shocks from an electric jar holding about a pint through the pelvis, one conductor being placed over the lumbo-sacral

[1] Lectures on Electricity and Galvanism in their Physiological and Therapeutical Relations. London Medical Gazette, 1847, p. 705.

[2] British Medical Journal. January 1873.

region, and the other just above the os pubis. Cases of amenorrhœa cured by the application of the continuous current have been recorded by Drs. Westring and de Molle; and Sir James Simpson has seen good results from the use of his *intra-uterine galvanic pessaries*, which are composed of copper and zinc. The induced current has proved beneficial in the hands of Duchenne, Schulz, Baierlacher, and my own. Even a lightning stroke has, according to Dr. Le Conte,[1] brought back the menstrual function in a negress seventy years of age, in a plantation in Georgia: in this person the period had ceased for more than twenty years; but after she had been struck by lightning, the menses were completely re-established, and continued with the utmost regularity for more than a year after the accident; at the same time the mammæ had become enlarged.

Electricity is especially valuable as an emmenagogue in young women, where the menstrual function has not yet been fully established in consequence of a torpid state of the vasomoter nerves of the ovaries and uterus; and also when the catamenia have been lost, after labour, or in consequence of a chill, or an emotion. Where amenorrhœa is caused by structural diseases of the ovaries and the uterus, the prognosis is unfavourable.

I have taken some trouble to determine the most effectual way of administering electricity in amenorrhœa. Duchenne has recommended faradisation of the womb, which is certainly effective, but not applicable to unmarried women. Experience has shown me that in many cases the catamenia are brought on, whatever part of the body may have been faradised; but that the most effectual way after faradisation of the womb is to apply one electrode to the abdominal parietes, and the other to the lumbar spine. It has frequently happened in cases under my care that the catamenia appeared after one or a few applications, when the faradic treatment was employed for an entirely different complaint. Thus, for instance, in a lady suffering from aphonia, I guided a mild current along the course of the recurrent nerve; a few hours afterwards the catemenia, which had not been expected for a week, appeared. In another lady I faradised the drum of the ear for nervous deafness and noises in the head; soon after the operation, the patient 'felt a general sensation throughout her body,' and the courses, which had before been tardy in their appearance, came on a week too soon.

[1] New York Journal of Medicine, 1844.

I subjoin a case of amenorrhœa which presents some interest partly on account of the advanced age of the patient, and partly because electricity was not used with the intention of effecting a return of menstruation :—

CASE 68.—A married woman, æt 48, was admitted as an out-patient at the infirmary for epilepsy and paralysis, under my care, on May 5, 1866. Six years ago she had a paralytic stroke which took away the use of the left side. She was then so ill for three months that her life was despaired of. She had had many miscarriages, and several children, but none of them were now living. Shortly before she had had the attack, the courses left her, at 42 years of age ; when she first missed them, she had a great deal of pain in the back, and suffered from sick headache. She had never seen a sign of them since. She had now nearly recovered the use of the arm, but there was almost complete anæthesia of the left leg from the knee downwards, and walking was very troublesome. I faradised the skin of the anæsthetic leg ; and after this had been done seven times, the patient informed me that she had been very much astonished by the period having returned. It came twice more, at a month's interval each time, after which I lost sight of her.

On the whole galvanisation is more effective than faradisation in amenorrhœa. A powerful current should be sent from the mons Veneris to the lumbar spine for fifteen to twenty minutes consecutively.

Chronic Metritis.—French surgeons frequently employ faradisation in inflammatory conditions of the womb ; and to M. Tripier[1] great merit is due for having improved the method of applying electricity in such cases (p. 426). Messrs. Beau and Fano have been equally successful with the faradic treatment of uterine disease as M. Tripier ; but English obstetricians are as yet singularly reluctant to employ it.

The influence of faradisation in uterine disease may be understood by considering the minute anatomical structure of the womb and its appendages, and the pathological nature of the principal diseases to which this organ is liable. The substance of the uterus consists of three different layers of organic muscular fibre-cells, which are intimately connected with one another, and pervaded by a considerable mass of nucleated connective tissue, with which the muscular fibres are so interlaced that it is almost impossible to isolate the several structural elements. The broad

[1] Manuel d'Électrothérapie. Paris, 1861, p. 548.

ligaments by which the uterus is kept in its proper position contain a continuation of these muscular fibres. Now, the chief morbid changes which occur in the tissue of the uterus and broad ligaments consist of atrophy of the contractile fibres, with effusions, and relative or absolute increase of connective tissue; and faradisation acts beneficially by inducing contractions of the muscular fibres and strengthening their tone, while at the same time it promotes the absorption of effusions, and checks the undue proliferation of connective tissue.

Chronic inflammation occurs after child-birth, repeated miscarriages, and mechanical injury to the parts, or from disturbances of the abdominal circulation, cold, mental emotions, sedentary habits, habitual constipation, and excessive sexual indulgence. Its chief anatomical feature consists, according to Scanzoni, of an excessive growth of connective tissue, which is formed by the organisation of the lymph effused between the muscular fibres of the womb, causing compression or even obliteration of the blood-vessels in some parts, and dilatation of the same in others.

Enlargement of the uterus without inflammation occurs after child-birth, in consequence of defective involution of that organ, and its symptoms are similar to those which are due to true chronic inflammation, viz. a sensation of weight, fulness, and dragging about the pelvis. Standing and walking are shunned, and if a little more exercise than usual is taken, severe pain is felt in the hypogastrium, the inguinal and sacral regions. The catamenia are mostly scanty, irregular, and painful; a leucorrhœal discharge is either permanently present, or occurs a few days previous to the period. Digestion is tardy and imperfect, there is frequently sickness, habitual constipation, and tenesmus about the bladder and rectum, and anæmia and a weak and irritable condition of the nervous system follow in due course.

Dr. G. Murray[1] has used Sir J. Simpson's galvanic pessaries for the relief and cure of sub-involution of the uterus, where the organ is heavy, larger than natural, and flabby to the touch; the os uteri open, or readily admitting the point of the forefinger; the anterior, posterior, or both lips thickened or elongated; and where there is an offensive discharge from the cavity of the womb, and an excess of menstrual flow. In one case of this kind, where the organ was also retroverted, and Hodge's

[1] The Lancet, vol. ii. 1868.

pessary had failed to remedy the diseased condition, Dr. Murray succeeded, by the introduction of the galvanic pessary, in reducing, in the course of a fortnight, the large flabby uterus nearly to its normal and healthy condition.

Displacements of the Womb are generally treated by the introduction of the uterine sound; but the result is often unsatisfactory, as the sound cannot always remain in the organ, and the moment it is withdrawn the body of the uterus falls back into its old position. The plan of introducing pessaries for rectifying the position of the uterus was a considerable improvement, as they not merely give mechanical support, but also tend to alter the tissue of the womb, so as to make it contract. Yet pessaries frequently give rise to irritation, which is chiefly due to the difficulty experienced in adapting a really well-fitting pessary to the individual case, and to the mischief which results if the pessary does not fit. The annoyance caused to the patient by wearing a pessary is also considerable; so that, if more extended experience should prove that faradisation is of substantial value in these conditions, a considerable therapeutical improvement would be effected.

a. Anteversion and Anteflexion of the uterus are generally owing to prolonged congestion, or the presence of a tumour, and connected with engorgement or hypertrophy of the anterior wall of the uterus. Such displacements are a frequent cause of sterility, for in 250 cases of sterility observed by Dr. Marion Sims no less than 103 patients had anteversion. If faradisation be used in such cases, we ought to act chiefly on the posterior portion of the womb, the positive electrode being introduced into the vagina, and the negative into the rectum. The latter should be moved about, during the application, so as to increase its exciting effect on the contractile substance of the womb.

b. Retroversion and Retroflexion occur chiefly after labour or miscarriages, when the uterus is large and lax, and its ligaments longer than usual, and it is therefore easily twisted and displaced. It may also occur where menstruation has been unusually profuse, and the womb enlarged and congested from other causes. For these cases M. Tripier recommends first to introduce an air-pessary into the rectum, in order to raise the fundus uteri, and then to put the negative electrode to the os, and the positive into the bladder; or instead of this a moistened sponge-conductor may be placed to the abdominal parietes. In unmarried women

M. Tripier recommends to have one electrode in the bladder, and a bifurcated sponge-conductor for both iliac regions.

c. In Prolapsus of the Womb bi-inguino-uterine faradisation is, according to M. Tripier, a useful auxiliary, although, when used alone, not able to cure the prolapsus.

The *irritable* or *neuralgic* condition of the uterus occurs without

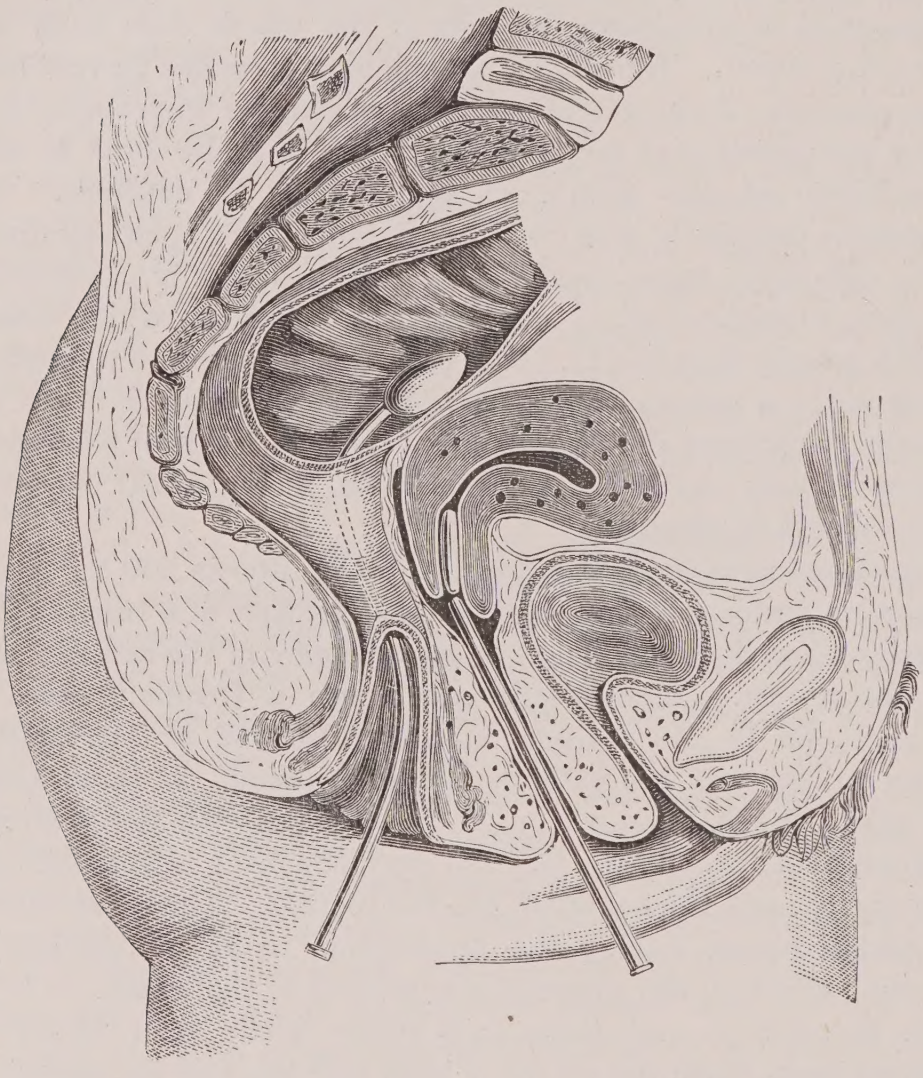

Fig. 147.—Faradisation of the Posterior Surface of the Womb.

displacement or inflammation, and is generally considered incurable. Patients of this kind live on their sofa for years, being compelled to assume the horziontal position by a constant pain in the uterus, which becomes worse on sitting or walking. Faradisation or galvanisation of the womb would probably be of use in this tedious affection.

Faradisation has often been successfully used for arresting

hæmorrhage from the uterus, and it appears certain that the organ may be rapidly and thoroughly contracted by it. The ultimate effect must, of course, depend upon the cause of the disease, which has to be treated according to the requirements of each individual case.

Stoppage of the Lacteal Secretion occurs after parturition, either from a sluggish state of the secretory nerves of the breasts or from malnutrition and atrophy of the glands; or the flow may be suppressed through fright or depressing mental emotions. Faradisation of the mammæ with moistened conductors is useful in this condition. Messrs. Aubert and Becquerel were the first to put this treatment into practice. I have treated several such cases with good results. Dr. Skinner,[1] of Liverpool, has likewise found faradisation beneficial where the milk was absent from the effects of mammary inflammation or abscess, or where it had been inadvertently stopped by the administration of astringents. The following is one of Dr. Skinner's cases :—

In August 1861 he was consulted by a lady, aged 36, on account of vaginal irritation and other morbid symptoms resulting from anæmia. The lady had been lately confined of her fifth child, and she was at the time suckling her infant. She was ordered moderate doses of tincture of iron thrice daily, but this medication was followed, in a few days, by a complete stoppage of the milk in both breasts. The right breast had never been used for suckling since an attack of mammary abscess some years before and he therefore faradised only the left breast. At the time of application the patient felt a distinct sensation as of 'a rush of milk to the breast.' On the 16th she reported that within a few hours of the faradisation a copious supply of milk was established in the left breast. He was then asked by the lady if he could do any good to the breast which had been so long useless as regards the function of lactation. He made the attempt, having little faith in the wished-for result, but was agreeably surprised to find that, after two sittings of little more than five minutes each, the right breast became as well supplied with milk as the left.

[1] The Galactagogue Properties of Faradisation, in Transactions of the Obstetrical Society of London, 1864.

XXI.—DISEASES OF THE SKIN.

Dr. Beard[1] has used his proceeding of 'central galvanisation' in certain diseases of the skin, such as prurigo, eczema, and lichen, with good results, without an application to the diseased surface. In obstinate cases of this kind, therefore, which do not yield to other treatment, galvanisation deserves a trial.

XXII.—TUMOURS.

Four different methods of applying electricity have been recommended and used for the removal of tumours. These are faradisation by moistened conductors (Meyer); the galvanic cautery (Heider and Middeldorpff); the external application of galvanic chains (Maurice Collis), and electrolysis (the Author).

a. Faradisation by moistened conductors has, in the hands of Dr. Moritz Meyer,[2] effected a considerable reduction of glandular tumours of large size, and in which surgical operations were inapplicable. The method is, however, very tedious, as hundreds of applications are required for radically influencing the nutrition of the tumour. Farado-puncture would probably be somewhat quicker in its action.

One of Meyer's cases was that of a young lady, aged 25, who suffered from a tumour on the right side of the neck, which had within four weeks of its first appearance increased so rapidly, that it had assumed the size of an adult's head. Various remedial measures were adopted, such as the internal and external use of iodine, the baths of Kreuznach, &c.; but as no effect was produced, and an operation was inadmissible, Professor von Langenbeck advised the use of electricity. At that time the tumour filled up the entire space between the lower jaw, the mastoid process and the linea semicircularis inferior of the occiput; then proceeded posteriorly towards the vertebral column, which was displaced to the left side; terminated anteriorly in the middle of the throat, and reached inferiorly below the shoulder-blade, the movement of the latter towards the spine being considerably impeded. The tumour did not appear to adhere to the bones, but was excessively hard, especially in its lower portion. The circumference of the

[1] Proceedings of the Medical Section of the American Medical Association. New York, 1873.

[2] Loc. cit. p. 407.

left side of the neck was six inches, and that of the right side fourteen inches. The right sterno-cleido-mastoid muscle could not be made out; the clavicula was completely covered by the tumour, and the head turned towards the left side, lateral motion towards the right side being impossible. The induced current was now sent straight through the tumour by means of metal plates covered with moistened sponge, for an hour or an hour and a half each time. After fifty-six such applications the bulk of the tumour had been reduced to one-half its previous size, and the upper part of it was much softer. After 144 applications the tumour was only one-third its original size. The circumference of the right side of the neck was then only ten and a half inches. The sterno-cleido-mastoid muscle could be plainly felt, the head was straight and could be turned slightly towards the right side, and the spine was no longer displaced towards the left. Altogether 273 applications were made. The improvement was steady, but did not progress, when the treatment was interrupted. At the end of the treatment the difference in the circumference of the two sides of the neck was only two inches, and the head could be easily turned towards the right side.

b. The galvanic cautery is a most powerful agent, by means of which many forms of tumour may be rapidly removed. It is chiefly applicable to superficial tumours, such as nævus, but has the disadvantage of generally leaving unsightly scars.

The galvanic cautery has been used in different ways for nævus. For pediculated tumours the wire loop is particularly useful; needles are introduced through the base of the tumour, and the wire is twisted round them. In other cases one or several platinum wires are introduced by a needle through the tumour, and the wires are then rendered incandescent (setaceum candens). These wires should be left in the wound until suppuration has supervened, and they can be easily withdrawn, as otherwise bleeding might come on. The porcelain cauteriser may also be used.

Dr. Maas[1] has collected 130 cases of nævus treated in this manner, most of which were operated upon by Professor Middeldorpff, of Breslau, and in which the loop was used 39 times, the setaceum 12, the porcelain cauteriser 17, and other forms 63 times. In 112 cases there was a complete cure, 11 improved, 3 died, and in 4 the result was not known. In 4 cases relapses

[1] Langenbeck's Archiv für Chirurgie, 1871, p. 520.

occurred; death resulted once from hæmorrhage which was not noticed, and once from trismus and tetanus.

The average duration of the treatment was not long; in many cases the eschar began to separate between the fifth and tenth days, and a good cicatrix was formed under it without perceptible suppuration. Over the knife the cautery has the advantage of no bleeding and no reaction. Injection of perchloride of iron is far more dangerous. According to Virchow there is no one proceeding suitable for *all* cases of angioma, and the surgeon will therefore have to choose the one best suited for each individual case.

M. Zielewicz[1] has collected fifty cases of amputation of the penis by the galvanic wire loop. In most cases the operation was done for cancer, only in one for gangrene, and once for an enormous papilloma; eight of these patients died of pyæmia. The danger lies in the laxity of the cellular tissue of the penis, the veins of the neck of the bladder and the prostate, and in the influence of nosocomial air. In private cases not a single death has taken place. No hæmorrhage ever occurred, in spite of numerous introductions of the catheter or bougies. There was no surgical fever afterwards. Contraction of the urethra only took place in one case, and then easily yielded to the use of bougies. A free use of carbolic acid would probably neutralise the influence of nosocomial air in such cases.

Dr. Voltolini, of Breslau,[2] was the first to use the galvanic wire loop for the removal of intra-laryngeal tumour. He claims for this proceeding that it is mild and painless, and that there is no hæmorrhage. He uses a platinum wire, which is so fine that the patient scarcely perceives the introduction of the instrument. The fear that the polypus might fall into the trachea he thinks unfounded, for experience shows that as soon as these growths are burnt off they are thrown out by cough. But even if they were to fall into the bronchi or lungs, he does not think that this would be a misfortune, for it is shown that foreign bodies, such as beans, peas, &c., which do so, do not kill immediately, but become dangerous merely by giving rise to secondary symptoms. This, he argues, would scarcely be possible through a polypus, which would, at the temperature of the body, no doubt soon become putrid, decomposed, and removed by absorption.

For *cancer of the tongue* the galvanic écraseur seems to be

[1] Langenbeck's Archiv, 1871, p. 589.

[2] Weitere Mittheilungen etc. Berliner Klin. Wochenschrift, No. 3, 1868. Langenbeck's Archiv, vol. vii. p. 693, 1865.

particularly valuable. Mr. Erichsen[1] has used it in a considerable number of cases with success. One of them is the following:—A man, aged 46, three months ago ran against a door in the dark with a pipe in his mouth. An indolent sore was the result, and this finally developed malignant tendencies. His previous health had been good, and he had never had any venereal disease. This last fact was important; for it is sometimes very difficult to distinguish between a syphilitic and a cancerous ulcer of the tongue, and the organ has certainly been excised before now under the idea that what was only a specific ulcer was malignant disease. In this case the disease was entirely confined to one lateral half of the organ, and the operation was performed as first suggested by Mr. Furneaux Jordan, of Birmingham. He first divided the cheek for about two inches horizontally backwards from the angle of the mouth; a few vessels bled freely, and had to be ligatured; he then divided the sublingual folds, and, having passed the wire of the galvanic écraseur through the centre of the tongue well behind the diseased part, cut slowly through the organ from behind forwards close to the raphe; he then cut across the base of the diseased half from within outwards in the same manner, thus removing one lateral half of the tongue. The cut through the cheek greatly facilitated the later stages of the operation; there was not the slightest hæmorrhage, but, had there been any, the arteries could have been secured with perfect ease. Finally, the cheek was brought together with hare-lip pins. Mr. Erichsen considers the galvanic écraseur one of the most valuable of the modern applications of physical science to medicine. The only point is to avoid undue haste, and to screw up the instrument slowly in proportion to the vascularity of the part operated on; hæmorrhage can thus be most effectually prevented.

The following case of *epithelial cancer of the perineum* has been recorded by Mr. Bryant:—Eliza L., aged 59, was admitted into Guy's Hospital, under the care of Dr. Oldham and Mr. Bryant, with an epithelial cancer the size of a crown-piece occupying the perineum, and involving the anus and portion of the recto vaginal septum. It had been growing for two years. On November 13, the patient being under the influence of chloroform, Mr. Bryant isolated the base of the growth by passing three large pins beneath it into the healthy tissues. He then passed round the base of the tumour beneath the pins a strong platinum

[1] British Med. Journal, Feb. 15, 1873.

wire, and fixed it to the écraseur, screwing it home. Junction was then made with the galvanic battery, and with a few carefully applied screws of the instrument the growth was removed, not a drop of blood being lost. A white, ash-coloured surface was left. Rapid recovery followed the operation, the patient leaving the hospital well on December 15.

The removal of a tumour so situated with the knife would have been very difficult, and must have been attended with severe and troublesome hæmorrhage.

The same surgeon has successfully treated a *spreading lupus of the face, by the cautery.* Eliza T., aged 30, came under Mr. Bryant's care with a spreading lupus, involving the whole of the nose and upper lip. It had existed for four years, and, in spite of all treatment, had steadily progressed. On November 6, 1868, it was freely cauterised. By the 19th the scab was coming away, a healing surface remaining. On the 26th the whole eschar had fallen off, and the wound was closing. By Dec. 8 the woman was well. She was seen on April 10, when it was difficult to make out the seat of the former disease, the cicatrices being indistinct and the skin natural.

Some surgeons have been in the habit of using the galvanic cautery just like the knife for almost all operations. Prof. Middeldorpff has amputated the thigh with it, and M. Verneuil uses it for tracheotomy. These are instances of 'riding a hobby too hard,' and are sure not to be followed by the majority of the surgical profession.

c. External Application of Galvanic Chains.—The late Mr. Collis, of Dublin, has used small batteries of zinc and copper wire wound on cylinders or plates of wood covered with felt, and rendered active by immersions in a weak solution of sulphuric acid. The negative pole is brought into contact with a plate of zinc, copper, or silver foil, laid over the tumour, and the positive is connected with a plate of copper laid somewhere on the general surface, with a preference to the spinal region. He has succeeded, by a prolonged application of these chains, in removing or considerably reducing glandular and some other kinds of tumours.

d. Electrolysis.—The electrolytic treatment appears to be the most universally applicable method of electrisation for the cure of tumours, although it is not nearly so rapid as the galvanic cautery, especially where the tumours are large. Its effects are

essentially slow in all tumours except those with liquid contents, and it tends rather to a profound modification of the nutrition of the parts involved than to a sudden destruction of the morbid growths. Electrolysis may therefore be described as a physiological rather than a mechanical remedy. The kinds of tumour in which electrolysis has hitherto proved chiefly successful are nævus, bronchocele, sebaceous tumours, hydatid tumours of the liver, and cancer.

CASE 69.—*Nævus of the Eye-lid; Electrolysis; cure.*

In July 1866 Mr. White Cooper requested me to see with him a lady, aged 28, who had a congenital nævus of the right lower eyelid, of the size of a pea, which it was thought desirable to remove. I gave the opinion that this might be safely done by electrolysis, without hæmorrhage, and without subsequent inflammation, suppuration, or sloughing; and we therefore met on July 23, in order to perform the operation. As the patient was of a highly sensitive constitution, chloroform was administered by Dr. Allan, of Hyde Park Terrace, the ordinary medical attendant of the lady. As soon as she was fairly under the influence of it, Mr. White Cooper introduced a needle connected with the negative pole of ten cells of the battery into the right half of the tumour, and I closed the circuit by placing a moistened electrode connected with the positive pole to the skin of the neck. The current was then allowed to pass for two minutes, after which the needle was withdrawn. Not a drop of blood was lost on withdrawing the needle. The patient recovered well from the chloroform, and said that she felt no pain in the part that had been operated upon, but merely a slight stiffness. The right half of the tumour appeared shrunk and shrivelled up, while the left half had not been altered in any way. This was an interesting circumstance, as it showed that even in so small a tumour as the one described the action of the current could be limited to that portion of it which was in contact with the needle. We met again on July 26, when the same operation was performed on the other half of the tumour; but this time the patient objected to the use of chloroform, and bore the trifling pain quite well without it. I have not seen the patient since; but received on October 13 a note from Dr. Allan, in which he expressed himself as follows:—'Mrs. —— is in the country, but last time I heard from her she said that the nævus had disappeared. A dozen years ago I wished it to be re-

moved; but no one would do it, and the able and esteemed oculist whom she then consulted deprecated all interference. At length I persuaded her to have another opinion (that of Mr. White Cooper). The result was your employment of galvanism, with the happy effect of complete obliteration of the evil.'

CASE 70.—*Nævus of the Orbit; Electrolysis; cure.*

A male child, aged 7 months, was sent to me by Dr. Schulhoff in December 1867 with a congenital nævus at the angle of the right eye, part of it being intra-orbital. It had the size of an almond and was highly vascular. When the child was five weeks old the tumour was on three different occasions cauterised with nitric acid. This (according to the parents) only took the colour out of it, but did not diminish the size of the tumour. At two months of age the child was vaccinated in the nævus, which for a time checked its growth; but it soon afterwards began to increase again. It was then twice more cauterised with nitric acid; but as this had no effect, Mr. Nunn, who was then consulted, advised the use of electrolysis. After five applications the tumour seemed entirely destroyed, and a scab was formed, which came off within two weeks. The tumour had a considerable tendency to reproduce itself, and it was therefore again electrolysed from time to time. When I last saw the child (October 1869) no trace of the tumour was left, but only a slight induration of the cellular tissue, for the removal of which I recommended the application of the tincture of iodine.

The following case of erectile tumour has been electrolytically treated by Dr. Lincoln, of New York.[1] 'The patient was a general officer, aged 33, in whom the swelling seemed to come on after a special effort in public speaking. On examination eighteen months afterwards a tumour was seen occupying the antero-inferior portion of the region defined by the sterno-cleido-mastoid and trapezius muscles and the clavicle of the left side. It was uniformly rounded in shape, two inches in diameter, and at its apex rose five-eighths of an inch above the natural contour of the neck. The sterno-cleido-mastoid muscle was more prominent on this side than on the other, and the trachea was displaced one-half of an inch to the right of the median line. To manipulation the tumour was elastic and readily compressible, but when pressure was removed

[1] The Medical Record. New York, 1872, p. 465.

it immediately resumed its former size and shape. It possessed no pulsation of its own; there was transmitted pulsation from the carotid beneath. Pressure applied to any one spot would neither increase nor diminish its size. It was well defined superiorly and posteriorly, but inferiorly it extended somewhat below and behind the clavicle, while anteriorly it embraced the edge of the sterno-cleido-mastoid at its lower quarter. The integument was of normal appearance, and entirely free from the tumour. During the act of swallowing it moved synchronously with the trachea, but not quite to the same extent. The whole size of the growth seemed to be as large as a large goose's egg. Anything that interfered with the circulation—as indigestion, emotions, or exercise—increased it to twice its usual size. If the patient held his breath and at the same time made an expulsive effort, the tumour became distended, as well as the veins of the neck and face. If he lay with his face down, the same condition was observed. If from any cause the size of the growth was temporarily increased, he suffered much pain, which often extended up the neck and to the head, had a sense of suffocation, and would occasionally lose his voice. The excitement of delivering an address induced these symptoms to such a degree that he was forced to decline every effort of the kind.

'The growth was diagnosed as venous erectile, and its treatment by electrolysis recommended. Dr. W. A. Hammond confirmed the diagnosis, and approved the recommendation.

'September 30.—Dr. Lincoln, in the presence of Drs. Hammond, Hackley, and Sass, electrolysed the tumour. The patient was put under the influence of chloroform, and four gilt-steel needles, insulated to one-half or three-fourths of an inch from their points, were then introduced into the four quarters of the tumour, the two upper being one and one-fourth inch apart and one inch above the lower, which were one inch apart. The two inner needles were connected with the subdivided anode, and the two outer with the subdivided cathode, and ten cells of the battery, which was working with a weak current, were used. Gradually the power of the battery was increased to fifteen cells. At the expiration of fifteen minutes the two lower needles were disconnected, so that the whole force was concentrated upon the two upper; at the expiration of fifteen minutes more the needles were removed. During the operation all the prominences of the tumour disappeared, and a delicate examination

detected a hard mass in its place. Not a drop of blood escaped on the removal of the needles. The skin over the tumour presented a bright blush, and the trachea had returned towards its proper position.

'Quiet was enjoined upon the patient, and the only application was a cold-water compress. The soreness, which was considerable after the operation, had so far passed away that at the end of three days he was walking about his room, and on the fifth day he left the city, relieved from all unpleasant symptoms and feeling quite well. The neck at that time presented no tumour, and the trachea was in its normal place.

'October 10.—Patient presented himself for examination. There was no tendency to a reappearance of the tumour; on the contrary, the induration in the neck was steadily diminishing in size.

'October 22.—The following is an extract from a letter received from the patient, who had already delivered several addresses: . . . . 'I am feeling very well, and there is nothing to indicate anything like a recurrence of my malady.'

Prof. Groh,[1] of Olmütz, has treated ten cases of nævus, with both poles in the tumour. They were all cured, and he thinks electrolysis, from the absence of danger and the avoidance of bleeding and disfigurement, preferable to any other operation hitherto devised for nævus.

CASE 71.—*Papillary Growth in the Arm-pit; Electrolysis; cure.*

A lady, aged 27, consulted me on November 21, 1866, on account of a small papillary and highly vascular growth which had first appeared in the axilla since the commencement of 1865, and had somewhat rapidly increased in size during the last few months. It was one-third of an inch long, and one-fourth of an inch wide in its widest part. I introduced a needle connected with fifteen cells of the battery into the base of the tumour, and allowed the current to pass for three minutes. No chloroform or ether spray was used. The current had not acted many seconds when a peculiar change was observed in the tumour, which lost its flesh-colour and became white, as if it had been frozen. When the needle was withdrawn, circulation in the tumour had evidently quite ceased. There was scarcely any

[1] Die Electrolyse in der Chirurgie. Wien, 1871.

pain during the operation, and none at all afterwards, nor was any blood lost.

November 23.—Tumour entirely shrivelled up, looking like a thin brown leaf adhering to the skin. The operation was therefore not repeated.

December 20.—The eschar fell off about a week after the operation. There is now no sign that there ever was a tumour, no scar nor even redness of the skin being perceptible.

CASE 72.—*Sebaceous Tumour of the Nose; Electrolysis; cure.*

A young lady, of considerable personal attractions, was sent to me by Mr. White Cooper, in April 1867, for a sebaceous tumour, which she had on the right side of the nose, near the eye, and which had existed for the last three years. The tumour did not give rise to any inconvenience, but spoilt her appearance, and she was therefore anxious to have it removed. A gentle current was used four times within ten days, after which the tumour had disappeared. I saw this lady again in October 1867, when not the slightest scar, or redness of the skin, was perceptible on the place where the current had been applied.

For *goître* (*bronchocele, Derbyshire neck*) the electrolytic treatment is also most valuable, because any other surgical interference with such tumours is so dangerous to life that few surgeons are willing to operate. In most of the cases which have been under my care, Mr. Prescott Hewett, Sir James Paget, Sir William Fergusson, Mr. Cæsar Hawkins, and other eminent surgeons, had been previously consulted, and pronounced any of the ordinary operations to be inadmissible. All these tumours were solid, and of very large size, and on that account required a long continuance of the treatment; but I believe that most cases of bronchocele, however large, may be cured by electrolysis, if the treatment be persevered in for a sufficient time. The cystic variety is, of course, much more rapidly curable by it than the solid.

Dr. Morell Mackenzie has given me, in the following lines, his experience with electrolysis in cases of goître:—

'I have used electrolysis, as recommended by Dr. Althaus, in several cases of goître, with a fair amount of success. In one instance in particular the treatment was rapidly followed by most satisfactory results. The following are brief notes of the case.

'Adelina G., age 17, a native of Savoy, came under my care at

the Hospital for Diseases of the Throat on June 14, 1867, on account of a goître which had been coming on for two years. The swelling affected both lobes, each of which appeared about as large as a moderate-sized orange. The hypertrophied tissue seemed to be of moderate density, uniformly distributed, and not nodular. The neck measured *eighteen* inches round, when the tape was carried over the prominences of the thyroid gland.

Treatment by electrolysis was at once commenced, two needles being introduced into the enlarged lobes and kept in for about ten minutes. This operation was repeated on the 16th and again on the 19th, on which day there did not appear to be any change in the form or size of the thyroid glands. On the 22nd the patient was seen again, and as she stated that she was sure that the throat was much smaller, it was measured and found to be reduced to *seventeen* inches. The reduction had principally taken place in the right lobe. A week later the left side was much smaller, the throat only measuring sixteen and a quarter inches. On July 5 it was reduced to fifteen and a half inches, and on July 11 it measured only *fifteen* inches. As there was now no apparent enlargement, the treatment, which had been carried out for less than a month, was discontinued. The patient had been previously treated by an English practitioner, who had given her medicine and tincture of iodine to apply externally. Neither had done her any good, and when she came to the hospital, treatment had been altogether suspended for three months. During the time that the electrolytic treatment was being carried out, no other remedies, either external or internal, were employed.

'So remarkably successful was the treatment that an Italian gentleman well acquainted with the case called at the hospital some months afterwards, in order to procure a battery of the same kind for use in the village in Savoy, whence Adelina G. had come. Although he informed me that there were many other similar cases in the same village, I did not recommend him to use electrolysis except under the direction of a medical practitioner.

'In several other cases under my care, benefit resulted from electrolysis. In one very dense hypertrophy, the results were negative. I consider that electrolysis is very useful in cases of moderate duration—six months to two years—and of yielding consistence.'

I will only add to this statement, that in the solid variety a

more powerful current is required than in the cystic (viz. from thirty to forty cells instead of ten or fifteen).

Dr. Wahltuch,[1] of Manchester, has treated a case of bronchocele successfully by electrolysis and the subcutaneous injection of iodine. 'The patient was a lady, aged 27. The tumour was of the size of a hen's egg, and had existed four years. Various means had been tried to reduce it, without effect. The electrolytic treatment was begun in July 1869. At first eight Daniell's elements were used, and one needle inserted. These were gradually increased to sixteen elements and four needles. The operation was performed first twice, then once a week, till January 5, 1870; in all, twenty-eight times. The mode of application was to insert into the tumour a needle connected with the negative pole of Althaus' permanent battery, and to close the circuit with a sponge on the skin from the positive pole. The current was kept up for ten minutes at first, gradually increasing to sixty minutes. After the twenty-fourth application the tumour was reduced to the size of a hazel-nut, and then remained stationary. The treatment was therefore suspended for a time, and then iodine was injected, the quantity and strength being gradually increased. From February to July Dr. Wahltuch operated sixteen times; and at the latter date the tumour had disappeared. In September there was no recurrence of it.'

The following is one of Drs. Beard and Rockwell's cases:—

'L. W., a girl aged 14 years, first observed four years since a slight enlargement of the thyroid gland. It rapidly increased in size, until December 5, 1871, when she presented herself for examination; it was one and a half inch in depth, and two inches in width, reaching to the anterior border of either sterno-cleido mastoid muscle. The mass was quite movable, and did not in any way cause inconvenience, excepting when she attempted to sing. Iodine, both internally and externally, had been used without appreciable benefit. For the first two months localised *external* galvanisation repeated twice a week was alone tried, resulting in no diminution in the size of the swelling, but in a very decided alleviation of the distressing sensation of strangling, which invariably occurred whenever she attempted to sing.

'Subsequently electrolysis was used, and to this date the tumor has steadily decreased in size, until it is now (June 1) one-quarter its original size, and the indications are that it will entirely disap-

[1] British Medical Journal, Nov. 5, 1870.

pear. The needle (a small glover's needle), has been introduced some twenty times, but as the pain produced is very slight no chloroform has at any time been used.'

Dr. H. Campbell has recorded the case of a maiden lady, aged 32 years, a native of Devonshire, who had a cystic goître of considerable size, existing for about ten years. It had been painted on various occasions with iodine, and both iodine and bromine had been taken internally, without any effect being produced on the tumour. He passed, on September 8, three needles into the cyst, and applied a power of fifteen cells for ten minutes. This was repeated on the 15th, and by the 30th its size was so reduced as to make it scarcely perceptible. He therefore did not continue the treatment. On November 2 he examined the patient, and beyond a slight thickening of the integuments over the original seat of the disease, and which marked the position of the sac, he could discover no trace of the tumour. A year later it had not returned.

Hydatid Tumours of the Liver.—Messrs. Durham [1] and Cooper Forster have, at Guy's Hospital and the Royal Infirmary for Children, Waterloo Road, successfully electrolysed eight large hydatid tumours of the liver. In one patient, who was under the care of Dr. Hilton Fagge, and who was operated upon by Mr. Durham, in June 1868, the dulness in the hepatic region measured seven inches vertically, the ribs on that side were bulged, and the intercostal spaces prominent. Two needles were introduced into the most prominent part of the swelling, one piercing the space between the eighth and ninth costal cartilages, and the other about two inches behind it, between the ninth and tenth ribs. The needles were passed into a depth of two or three inches. One of them was then evidently free in fluid, for it could be moved about and rubbed against the other. The posterior needle doubtless passed through the diaphragm, as it was jerked about by the respiratory movement. Both needles were connected with the negative pole of ten cells of the battery, freshly charged. The anode, connected with a moistened conductor, was placed between and near the needles. The current was allowed to pass for twenty-five minutes, and during this time there was a crackling feeling under the finger, as of emphysema, owing to the development of hydrogen from the liquid of the cyst. After the operation there was some pain for four or five

[1] Medico-Chirurgical Transactions, London, 1871, p. 1.

hours. In the evening the temperature was 100·9°, and the patient did not sleep well that night. Next day the temperature was 99·6°, and on the morning after it had risen to 101·2°. At this time the hypochondriacal tumour had greatly disappeared, and the man expressed himself as feeling quite well. On examining the right side of the chest, however, Dr. Fagge was a little startled at finding absolute dulness behind, up to the fourth or fifth dorsal vertebra; and over this extent of thorax there was loss of vocal vibration, marked tubular respiration, and ægophonic character of the voice, which afforded conclusive evidence of a large effusion of fluid. There was very slight pain about the points where the punctures had been made, but no pleuritic pain. The man lay on his back and felt quite comfortable. The liquid had evidently been squeezed through the puncture in the diaphragm into the pleural cavity. The man went on perfectly well, and the chest symptoms disappeared rapidly. Twenty days after all traces of the abdominal tumour had disappeared.

The ease with which this patient recovered from the accidental effusion of decomposed hydatid liquid into the pleural sac, adds one to the many instances which I have myself observed of the extraordinary tolerance of the system with regard to electrolytic operations in which only the negative pole is employed internally. If that needle, which in Dr. Fagge's patient passed through the diaphragm, had been connected with the positive pole, the life of the patient might have been placed in great jeopardy, as it would have introduced irritant metal salts into the cavity of the pleura.

Mr. Durham and Dr. Hilton Fagge claim for the electrolytic treatment of hydatid cysts of the liver the following advantages: 1, that the operation itself is altogether free from danger; and 2, that it is not liable to set up suppuration within the cyst, and thus indirectly to involve the patient in serious risk.

How does electrolysis act in such cases? It appears reasonable to assume that the decomposition of the fluid renders this poisonous to the parasite. It is not to be expected that a creature whose normal medium is a solution of chloride of sodium, could continue to live, when for this a solution of caustic soda has been substituted.

It is advisable to use two needles in the sac, because if they can be made to rub together, it shows that the contents of the tumour are fluid; besides which they afford an increased

surface for the electrolytic action. Tapping is followed by suppuration in some cases, while electrolysis is not. The opening made by a trocar is larger than that made by the needle, and may allow the escape of scolices into the peritoneum.

Ovarian Cysts.

Dr. Fieber, of Vienna,[1] has successfully electrolysed an ovarian cyst which occurred in a needlewoman, aged 32. The patient had had a bad fall in November 1866; she suffered from various symptoms afterwards, and first noticed a tumour the size of a fist in January 1867. When she came under treatment in June 1870, the tumour had the size of the head of an adult; it was not tender, hard, nodulated, and occupied a space commencing half an inch above the umbilicus, and ending one inch above the os pubis; its width amounted to six inches. The first electrolytic operation was made early in June, and it was repeated eleven times. At first the tumour decreased only slowly, but at last rapidly. In March 1871 it had been reduced to the size of a fowl's egg, and gave no inconvenience. Dr. Fieber strongly recommends to use electrolysis in all cases of ovarian cysts before resorting to ovariotomy. We think that in unilocular cysts it might supersede the latter, while in the multilocular variety ovariotomy would always be preferable.

Mr. Callender[2] has used the same treatment in a case of *recurrent fibroid disease*, in a patient who, in December 1868, first discovered a tumour in the right loin; a year later it was removed by Sir James Paget, and proved to be a recurrent fibroid. After nine months an enormous mass was again cut out. Six months later he came under Mr. Callender's care, and the growth was again removed; and five months after this a fourth operation was required. On each occasion the growth had attained a great size; and on the last two the twelfth rib was exposed, and the tumour had to be dissected off from the capsular fat of the right kidney. Before the large wound from the last operation had closed, one or two isolated nodules, growing up in the granulating surface, made their appearance, and it was to these that the electric current was applied. The patient was fifty-one years of age, and his general health was excellent. Two needles were used; one, from the positive pole, was inserted into the growth;

[1] Wiener medizin. Presse, 1871. No 15.

[2] British Medical Journal, February 10, 1872.

the other, connected with the negative pole, was applied to its surface. The operation was painless. Some immediate sloughing was caused about the track of the first needle, twelve cells having been used for six minutes; but in the course of a few days, and after a repetition of the operation, the entire mass, about the size of a marble, seemed to melt away and disappear. The wound has since healed soundly over this portion of the granulating surface, whilst a fresh outbreak of the tumour at quite another part of the wound is being successfully treated on the same plan.

In some other cases, treated by the same surgeon, the effect was not so marked, or altogether negative; but this was perhaps to some extent due to the treatment not having been carried out systematically.

Dr. Holden,[1] of Larne, has treated a case of recurrent fibroid tumour in a young woman who had, two years before he saw her, a large tumour occupying the infraspinous portion of the scapula, which was at that time removed in the Belfast General Hospital by Dr. Murney, and found to be recurrent fibroid. Its reappearance commenced above the scapular spine, gradually spreading until a large mass filled the supraclavicular space, pressing and involving all the important structures, and slowly advancing with fatal grasp on the trachea. In order to stay or divert this threatening extension of the tumour, he tried electrolysis. The battery used was Smee's, with six cells. Into the substance of the most accessible portion, and close to the trachea, two negative and two positive needles were introduced. The continuous current was thus applied for a quarter of an hour, sometimes longer, three or four times a week for a month, with the following result. The part of the tumour acted on had certainly paused in its progress, and even diminished in its size, but the surrounding portions had as decidedly assumed a more rapid growth.

On this case we should remark that the very slight power used, viz. six cells of Smee's battery, could not be expected to have a very decisive influence on the tumour, unless the applications had been very much longer, say 12 or 24 hours at a time, instead of fifteen minutes; or a much greater galvanic power, say 25 or 35 cells of Smee's, should have been used for a short time. We can therefore attach no importance to the unsuccessful result of the treatment in this case. It would

[1] British Medical Journal, March 16 1872.

likewise be most difficult to decide whether the more rapid growth which was observed was really owing to the influence of electrolysis, or whether it would not likewise have occurred if the tumour had not been interfered with at all.

Cancer.—In my paper 'On the Electrolytic Treatment of Tumours and other Surgical Diseases' (1867), I expressed myself as follows concerning the value of electrolysis in cancer:—'A larger experience than I command at present is necessary to decide the question, whether the electrolytic treatment will eventually supersede the methods now in use for the removal of cancer. . . . Electrolysis, however, may be applied to every variety of cancer, and it seems to be of little consequence whether or not the tumour adheres to the bones—a circumstance which often renders removal by the knife difficult or impossible. I believe that in this disease the electrolytic method will be found generally useful, not merely by removing the present tumours, but also by so modifying the nutrition of the parts concerned that no relapse is likely to take place there; and it may thus indirectly help towards the eradication of the cancerous diathesis. It is a curious fact that the peculiar lancinating pains of cancer generally seem to disappear, or at least to diminish considerably, soon after the commencement of the electrolytic treatment, and long before the whole tumour has disappeared.'

One point appears already settled in this matter, and that is, that *there is no better means for relieving the pain of cancer than electrolysis*, which appears superior in this respect to our most approved narcotics. Observers are quite unanimous in this particular. Professor Schwanda,[1] of Vienna, has treated a case of cancer of the breast, in which, six weeks before death, the pain, spasms, and sleeplessness were so severe as to defy all the usual means for the relief of those symptoms. The patient could not rest in bed, but had for three nights and days been without sleep, and 'contracted with pain.' Professor Braun, under whose care the patient was, then advised the use of the constant current, and after two applications the patient felt so much relieved that she could assume the horizontal position in bed; the use of the current was continued up to the time of her death, and was the only thing which did any good.

Mr. Lawson Tait[2] has recorded a case of encephaloid cancer of

[1] Zeitschrift der Wiener Aerzte, March 1869.

[2] Transactions of the Clinical Society of London, 1871, p. 145.

the femur treated by electrolysis, in which this effect of the treatment was most marked. The patient generally took sixty or a hundred grains of hydrate of chloral, and had twenty-four grains of morphia injected subcutaneously every twenty-four hours, besides inhaling chloroform occasionally; but after two electrolytic applications she was for four days absolutely free from pain, and required neither opiate nor chloral. During that time it was also possible to lift her and change the bed-linen without putting her under the influence of chloroform, which had not been done for three months previous to the application of the current. On the fifth day the pain recurred slightly, and required the administration of sixty grains of chloral. Up to the seventh day it grew more and more severe, and then the electrolytic application was repeated, after which she was free from pain until her death. On the thirteenth day it was evident that she was sinking from exhaustion and irritative fever, and she died on the fourteenth, without the recurrence of the pain.

With regard to *epithelioma*, there is considerable evidence that electrolysis, with both poles in the tumour, is able to eradicate the same. Prof. Groh[1] has treated eighteen cases, of which thirteen were cured, two improved, in two there were no results, while one ended fatally. In these cases he thinks it necessary to destroy not only the growth itself, but also its next neighbourhood, in order to avoid subsequent infection. In some of these cases, only one, in others two or more applications, were necessary. In one case there was not only ulceration of the lower lip, but also of the whole chin; the corresponding part of the lower jaw was covered with detritus; some teeth had fallen out, and those remaining were so loose that they could be extracted by the finger. Both submaxillary glands were engorged. Four applications were sufficient to produce destruction of the tumour, which was followed by good cicatrisation.

Messrs. Beard and Rockwell[2] report to the same effect. One of their cases was that of a female patient, aged 65, who noticed, in September 1871, a little hard lump, the size of a pea, on the left side of the under lip. By January 19, 1872, it had extended from the angle of the mouth along the lip to the median line. The surface presented a warty appearance, was exceedingly hard, and bled readily. Localized galvanization (external) dissi-

[1] Loc. cit.

[2] The New York Medical Record, 1872, p. 292.

pated almost completely the excessive pain in the diseased part. On January 26 five uninsulated needles were introduced into the lip, *around and beneath* the tumour, so as to entirely separate the healthy from the unhealthy tissue, and a current of considerable tension from eighteen cells was allowed to pass for twenty-five minutes. Equal parts of chloroform and ether were administered.

Inflammation and suppuration followed, and in two days the entire tumour had sloughed away.

By February 2 the inflammation had subsided, and the surface was covered with healty granulations. Improvement continued until February 23, when the surface had entirely healed, and the patient was discharged as cured, with a well-formed lip.

In *scirrhus* the results of electrolysis have as a rule been negative. Dr. Neftel,[1] of New York, has, however, quite recently, in an elaborate paper on this subject, attempted to show that electrolysis is the best treatment for primary scirrhus. He argues with Virchow, that malignant tumours may be at first quite local, and that the dyscrasia is only secondarily developed. There is no primary permanent dyscrasia; only predisposition, but no actual disease is inherited. The local origin of cancer is also rendered probable by the fact that the primarily affected organs are generally those which are exposed to mechanical and chemical injury, such as the skin and mucous membranes, the lips, tongue, œsophagus, stomach, rectum, womb, testicle, and more especially the breast. The latter cannot escape any accidental injury, as it rests on an osseous base, cannot be easily pushed away, and is likewise fixed by the stays. Cancer of the liver has suddenly become developed after impaction of biliary concrements in the common duct, causing irritation.

That nevertheless excision does not generally lead to a cure Neftel explains by the circumstance that the whole of the diseased mass is not removed, inasmuch as apparently healthy parts when examined show that they have already become infected. Neftel says that the duration of life is shortened, and that the morbid process progresses more slowly, as long as the primary tumour has not been removed, and seems to concentrate itself in that tumour alone. After its removal, however, the disease progresses more rapidly, and the morbid elements which have remained develop greater activity, and the fatal issue is accelerated. The

[1] Virchow's Archiv, vol. lvii. 1873, p. 249.

same occurs whether the tumours may have been removed by the knife, or by caustics, the actual or galvanic cautery, &c. Electrolysis performed in a certain manner, on the contrary, may not only destroy the tumour, but also cure the disease, inasmuch as it acts not only on the neoplasma, but also on the surrounding parts, which although apparently healthy, are nevertheless already infected.

It will be observed from this argumentation that Dr. Neftel appears to be entirely unacquainted with the method of operation introduced by Mr. Campbell De Morgan, and which consists of a thorough cauterisation of the wound, after excision, with a solution of chloride of zinc, by which any disease-germs which the knife has been unable to remove, are destroyed.

According to Neftel, the electrolytic effect differs from cauterising by acids or alkalies chiefly in this particular, that the ordinary caustics have an entirely local effect, while the electrolytic effects spread wherever portions of the current travel, that is, throughout the whole system.

The histological researches of Kühne, Engelmann, Golubew, and others, have shown that electricity has a powerful effect on the protoplasma, the vital properties of which may be modified or destroyed by it. This molecular and general effect is, according to Neftel, the most important influence of electrolysis. Hydrogen is a powerful poison for the protoplasma; and the protoplasma of the cancerous cells appears to be so altered by electrolysis that they lose their vital properties. Cancerous cells are more easily destroyed by the galvanic current than healthy cells, as is seen under the microscope. Only a feeble current should be used in such experiments, because a powerful one destroys both kinds of cells rapidly. This shows the possibility of altering electrolytically the cancerous elements, without acting too much upon the healthy parts. The neoplasma might, therefore, be easily destroyed if it were not endowed with an immense power of proliferation, whereby the action of electrolysis is to some extent neutralised.

The cachectic appearance generally does not exist in the commencement of the disease; on the contrary, the patients generally look well, and the dyscrasia only appears in the later stages. The cachexia is produced by the pain, the suppuration, and the local destruction caused by the tumour; and more especially by the absorption of the decaying elements of the neoplasma.

This general condition of the patients is improved by electrolysis in a remarkable manner, even in bad cases; the lancinating pains disappear; appetite, digestion, and sleep return; the patients who formerly despaired altogether become inspirited, and hope for a complete cure. This change is no doubt owing to the destruction of the decayed parts of the tumour, which are by electrolysis resolved into their innocuous chemical constituents, viz. hydrogen and alkalies.

Neftel therefore recommends to resort to electrolysis even in incurable cases, as a palliative remedy, because it improves the general condition of the patient, and relieves pain. It is in this respect entirely different from excision, cauterisation, and the galvanic cautery, because these procedures accelerate generalisation and the fatal issue. According to him, electrolysis by means of needles is not sufficient to cure cancer, even where it appears to be curable; but persistent external application of the current should be added to it. A powerful current does not answer, because its effect is concentrated at the point of application, and destroys the texture it touches, without attacking the more deeply seated morbid tissues. A feeble current does not act so much upon the place of application, but goes more in the way of the needle-tracks, which serve as conductors of the current into the depth of the tumour. The operations with needles therefore serve a double purpose; they at first cause powerful chemical decomposition, and afterwards give to the current the proper course whereby it can develop its chief effect.

Another advantage of the electrolytic treatment is that it is devoid of danger; there is no febrile reaction; and the patients can do anything they please during the progress of treatment.

Neftel has, amongst unsuccessful cases, recorded the following successful one:—

A married woman, aged 43, mother of three children, had right mammary abscess after her first confinement. In April 1869 she received a blow upon the same breast; but as the pain soon disappeared, she gave no further attention to it. In August of the same year she commenced to feel pain in the same breast, and discovered a hard lump of the size of a walnut. This lump gradually increased, and grew together with the skin; shooting pains supervened, and spread to the right arm. The patient became anæmic, chachectic, and very thin. When seen in April 1871, the tumour had the size of a small orange; the nipple was

retracted. The axillary glands were not affected. The brother of the patient suffered from epithelioma of the eyelid. The treatment was: Eloctrolysis by three needles connected with the cathode; thirty-five cells, thirty minutes, under chloroform. Repeated on April 28, May 2, and May 6. The general condition of the patient improved. From May 8 to July 10 daily applications of a feeble current; a small cathode in form of a plate was applied by means of a moist compress to the tumour, more especially to the needle-tracks, the large anode being placed in the neighbourhood. The places were changed every few minutes; six, eight, ten cells, from fifteen to thirty minutes. Small eschars were formed, where the cathode was again applied. The tumour gradually became smaller, and at last disappeared. On July 10 the patient went home, apparently perfectly well; but treatment with four cells was continued at home for several months longer. Twelve months later no relapse had taken place.

Neftel makes it a rule to perform the introductory needle-operations at short intervals, and immediately to continue percutaneous treatment with a feeble current. If this be omitted, the retrogressive metamorphosis of the tumour ceases, and at last the growth becomes even more rapid than before.

The general result at which this observer has arrived is, that cancer is curable by electrolysis. It is true that some of his cases which were cured may have been non-malignant; but certainly some were malignant; and many who afterwards died, and where malignant disease was histologically proved, were much improved by the treatment.

The principal thing seems therefore to be, to commence the treatment in the initial stage, before the complaint has become generalised. This stage lasts a variable time. Scirrhus of the breast may attain a considerable size, without affecting the axillary glands, and may be cured by electrolysis, even when it has lasted for years, and has become very large. On the other hand, the soft medullary tumours, even small ones which have only lately appeared, have great tendency to rapid generalisation. Where the neighbouring glands are already affected, the prognosis is doubtful, and treatment longer and more difficult. Everything depends then upon the circumstance whether all the affected parts may be reached and thoroughly destroyed. If the tumour has grown together with the deeper parts, and secondary deposit has taken place in the internal organs, the disease must be considered incurable. This stage must be prevented. The task of the

practitioner therefore should be to treat at once every suspicious or malignant tumour by electrolysis, whereby the disease may be permanently arrested, and the incurable stage prevented.

Prof. Mussey,[1] of Philadelphia, has recorded a case in which a cancer of the dorsum manus had beeen excised. A relapse took place, and as the bones and all other parts of the hand were affected, amputation of the arm was thought of. Electrolysis, however, was used, with the result that the large ulcerating tumour entirely disappeared and became cicatrised; and after two years no relapse has taken place.

According to Bruns[2] electrolysis acts only by cauterisation, followed by suppurative inflammation, granulation and cicatrisation, with shrinking of the tumour. This is certainly incorrect. Small tumours disappear without ulceration and suppuration; they become simply smaller and softer, and at last vanish. In these cases it is necessary to insulate the needle, so as not to affect the skin; or if not insulated, it is rapidly extracted, and afterwards the cathode-plate daily applied to the needle-track. Moreover, one often sees a clear, transparent, inodorous, alkaline liquid exuding from the needle-tracks; this is nothing like pus or putrid matter, but simply the tumour decomposed and fluidified by electrolysis.

In a hard tumour of moderate size and of slow growth, Neftel proceeds as follows:—Two to four needles are introduced at equal distances from one another, connected with the serres-fines conductor, and a large anode placed at some distance from the tumour. The circuit is closed metallically with a few cells, and rapidly brought up to thirty-five or forty cells. After the anode-plate has been a few minutes on one part, it is made to change its place, so that it shall have gradually encircled the whole tumour. This is done so that the whole tumour may be acted upon, and the skin not be injured by the anode. After twenty or thirty minutes, the number of cells is gradually diminished, and one needle after the other removed. If no chloroform be used, the increase and diminution of the current must be done very gently and gradually. This may be repeated three or four days afterwards, only the needles are inserted in other parts of the tumour; and again three or four days after that. After this daily applications of a feeble current are made. A small flat

[1] Transactions of the American Medical Association. Philadelphia, 1872.
[2] Galvano-Chirurgie. Tübingen, 1870.

cathode covered with a moist compress is placed on the tumour for a few minutes, while the large anode is held at a greater distance from it. The cathode is then placed on another part of the tumour, on the needle-tracks, and the anode just opposite to it. Such an application may last fifteen to thirty minutes; it should not be painful, and not cause cauterisation. About ten or fifteen cells are used. The electrodes should not be too near each other, so that the current should not run the nearest way, but penetrate the whole depth of the tumour. The needle-tracks are the best roads for the current, as they offer only slight resistance to passage. This may be continued for months, and the patient may at last do it herself. The eschars gradually fall off, and the sores which remain heal under the influence of a feeble current. If a cavity be formed, it is filled with moistened cotton-wool, to which the cathode plate is applied, or a probe-like cathode is pressed on to it. When the tumour is gone, and the sores have become cicatrised, the treatment should be continued for some time, at first daily, and afterwards two or three times a week.

If the tumour is larger, the initial needle-operations are so far modified that after the needles have been about ten minutes in the tumour, one after the other is extracted and introduced into other parts, until they have penetrated the whole mass of the tumour, its centre as well as its periphery. It is not good to use more than four needles, because if there are more, the effect in some of them is very feeble. As a rule no bleeding occurs; but if it should, it can be easily arrested by applying the anode plate to the bleeding part.

If the tumour be enormous, the whole organ transformed into cancer, and extensive ulceration be present, the growth be rigid and the quality medullary; or if it threaten to invade large vessels and other important parts, an anode needle of platinum is introduced perpendicularly into the centre of the tumour; four cathode needles at the periphery horizontally through the base of the tumour, at a small distance from each other; metallic closure, and intense current. After twenty minutes one needle after the other is removed, in pauses of several minutes, and again put into fresh parts, until the whole tumour is undermined; care being taken that the cathode needles never touch the anode needle. Finally all the cathode, and likewise the anode needle, is removed. This operation may last from thirty to ninety minutes. During the operation the tumour

assumes a livid discoloured hue, and afterwards becomes quite black. In seven or ten days either the whole or part of it is thrown off, but the gangrene does not spread beyond the cathode needles.

Further observations on this subject are highly desirable.

With regard to *secondary cancer*, we have an observation by Groh which is favourable, and another by Neftel,[1] which is remarkably so. Groh employed prolonged electrolysis with a feeble but perfectly constant current, administered for several days and nights consecutively; while in Neftel's case three comparatively short needle-operations were used.

Neftel's patient was a member of the American Congress, and aged 56. In 1868 he consulted a number of eminent surgeons, both in London and Paris, who were unanimous in their opinion concerning the cancerous nature of the tumour, which occupied the left mammillary region. They all refused to operate, as the case was even then looked upon as one of general infection of the system with the cancerous poison, and it was therefore thought that a surgical operation would only accelerate the inevitably fatal result. The tumour was, however, eventually excised by Dr. Marion Sims, in Paris. Soon after the wound had healed, the axillary glands of the left side began to enlarge, and formed, in January 1869, a hard swelling of the size of a fist. The patient and Dr. Marion Sims were both at that time in New York, and the same surgeon again excised the tumour, which was exhibited at a meeting of the Pathological Society of New York, and microscopically examined by competent histologists, who pronounced it to be cancerous. Diffuse erysipelas set in after the second operation, with fever and severe constitutional disturbance; the temperature rose to 106°, and there were rigors and delirium. The patient rallied after a time, but the wound afterwards healed very slowly. Cicatrisation was hardly completed when a fresh tumour began to develop itself in the right mammillary region. This grew rapidly, and soon attained the size of an orange.

Further surgical procedures now appeared inadmissible, especially as the general health of the patient had given way. Dr. Neftel therefore proposed to employ the electrolytic treatment. He introduced on three several occasions, in April and May 1869, at first two, then three, and at last four gilt needles separately into the tumour, and connected them, by means of the

[1] Virchow's Archiv, November 1869, p. 521.

serres-fines conductor, with the negative pole of a Daniell's battery, the positive electrode being placed on the skin in the neighbourhood of the tumour. He began with a current of ten cells, which was gradually increased to thirty. The first operation lasted two, the second five, and the third ten minutes. The needles were removed without any hæmorrhage taking place. Immediately after the operation the tumour appeared considerably larger, from the hydrogen which had become evolved in it, but it was softer and more elastic to the touch. No fever or any other unpleasant symptoms supervened; on the contrary the patient, who had been very feeble, anæmic and cachectic, became stronger from day to day, and the tumour gradually began to shrink. Two months after the first application, it had almost entirely disappeared; and three months after no trace of it was left. The general health of the patient had improved *pari passu*, and was, when last seen, excellent. No fresh tumours had appeared anywhere.

In this case the percutaneous treatment was continued for about twelve months, daily, the cathode being placed to the region of the tumour, and the anode in the neighbourhood, for from fifteen to thirty minutes. The patient died three years afterwards of another complaint, no relapse having taken place.

Lipoma.—Fat being a very imperfect conductor of electricity, lipomas offer more resistance to the electrolytic treatment than other tumours. They may, however, be removed by it in course of time. Free alkali being, by the action of the negative pole, developed from the blood-vessels and the connective tissue in which the fat is imbedded, the tumour is gradually changed into an emulsion, which is absorbed into the general circulation.

Slight bleeding may sometimes occur on removing the needles, if the tumour is highly vascular, the galvanic power employed very low, and the needles are too rapidly withdrawn; but it can always be stopped by again applying the negative or the positive pole to the puncture. As a rule, however, there is no appearance of blood, if the operation be carefully performed.

In leaving this subject I must lay stress on the importance of having a perfectly satisfactory action of the battery, as insufficient galvanic power has in such operations, to my knowledge, been a cause of disappointment. As regards the number of cells to be employed, we must be guided by the nature of the tumour. For cysts and tumours with soft contents less power is required than for hard swellings.

XXIII.—WOUNDS AND ULCERS.

Faradisation is useful where ulcers are slow to heal; and after amputations, where the stump is in a bad condition. Some years ago, I treated by this means a patient upon whom Mr. Spencer Wells had performed amputation of the forefinger. Cicatrisation had been very tardy, and although the wound healed at last, the stump remained livid, very soft, was exceedingly sensitive to touch, and bled easily. Under the influence of faradisation, it became much firmer, acquired a healthier colour, was less sensitive to touch, and never bled again. Mr. Mitchell Henry has informed me that he has, in patients who were under his care in the Middlesex Hospital, found the same means very beneficial for improving the secretion of ulcers; and Dr. Ruschenberger, of the United States' Navy, has successfully used the induced current for the cure of unmanageable decubitus. Mr. Nunn has also adopted this mode of treatment for the sequelæ of mammary abscess, in sinus of the breast, and the painful œdema, which is so apt to remain after the more acute phenomena of inflammation have subsided. In several instances Mr. Nunn has seen, after one application, the indolent edges of the fistulous opening assuming a healthy appearance, and the dull red colour of the infiltrated skin giving place to a tint peculiar to resolution. In all these cases faradisation acts by stimulating the vasomotor nerves, in consequence of which the activity of the blood-vessels is increased, and the absorption of exudation-products is promoted.

The continuous current is likewise valuable in such case. Mr. Spencer Wells,[1] who has used it a good deal, has come to the conclusion that there is no other means so capable of producing a rapid growth of healthy granulations, and that often a very beneficial change is effected in the condition of ulcers within twenty-four hours. Mr. Wells found that if two slight excoriations, two ulcers or suppurating surfaces on a limb or any part of the body, were subjected to the action of a single galvanic pair, the zinc being applied upon one and the silver on the other, the surface beneath the silver rapidly cicatrised, while that beneath the zinc was in two days converted into a superficial eschar.

[1] Appendix to Dr. Golding Bird's Lectures on Electricity and Galvanism. London, 1849.

To insure the passage of the current it is not necessary to denude, but only to moisten the cuticle. If the plates be still kept applied, the eschar extends to the subcutaneous cellular tissue, and presents all the characters of a slough produced by caustic potash, except that the dead tissues are a little less compact. After the separation of these sloughs cicatrisation under ordinary applications is very tardy, but sets in at once if the silver plate be applied, the zinc being fixed on some neighbouring part.

Messrs. Beard and Rockwell report the case of a woman, aged 40, who, on May 1, 1871, fell and injured the arm immediately above the external condyle. The pain was excessive, and continued to distress her for several weeks, when a small ulcer made its appearance and enlarged until it was two inches in diameter.

The patient applied for treatment, July 18. The ulcer was covered with a dark-coloured scab three-fourths of an inch, partly lifted from its resting-place by exuberant and unhealthy granulations. The scab was removed, and a wet cloth in connection with the positive pole was applied to the diseased part, while the negative was placed on an indifferent but approximate part. The galvanic current was used. She suffered no more pain after the second *séance*, and as the applications were repeated the ulcer rapidly healed, until August 30, when the part was covered by sound healthy skin.

The same observers have also treated a syphilitic ulcer successfully by electrolysis. A woman, aged 40, suffered three years since from a number of syphilitic tubercles and ulcers about her hips, thighs, and vulva. They persisted a long time and gave her much annoyance, but finally healed, with the exception of one on the inside of the thigh. It was elevated nearly half an inch above the surrounding surface, was excessively painful, and discharged an offensive secretion. A needle connected with the positive pole was passed through the base of the elevation, and a current of moderate tension allowed to pass for a few moments. This application dissipated all pain, and after the third *séance*, given several weeks after the first, soon healed, and the patient was discharged from the dispensary.

XXIV.—INTRODUCTION OF DRUGS INTO THE SYSTEM BY THE AID OF ELECTRICITY.

Fabré-Palaprat[1] has endeavoured to introduce drugs into the human body by the aid of electricity. He fixed a compress, moistened with a solution of iodide of potassium, and covered by a platinum disc connected with the negative pole of a voltaic pile of thirty pairs, on one of his arms, and another compress, moistened with a solution of starch, and covered by a platinum disc connected with the positive pole of the battery, on the other arm, after which the current was allowed to pass for some time. He says that after a few minutes the starch acquired a blue tinge, showing that the iodine had travelled from one arm to the other.

From this and other observations he concluded that medicinal substances might by the galvanic current be introduced into the system, and then *ad libitum* either be allowed to remain in it, or removed from it after having traversed the body.

Our present physiological knowledge enables us to say that it is impossible, by any contrivance, to prevent the elimination of most medicinal substances from the body; and one of Fabré-Palaprat's propositions may therefore *à priori* be eliminated from the inquiry. The other proposition, viz. that electricity may serve to introduce drugs into the system, is likewise untenable, as those who have repeated Palaprat's experiments have never been able to perceive any passage of iodine from the negative pole of the battery through the human body to the positive pole. We must therefore conclude that his observations have not been made with sufficient care, and that he was thereby led to erroneous deductions. Perhaps he was hardly fit for making such observations, as, according to his own account, he suffered from 'ecstatic spasms' about the time when he worked on this subject.

In 1846 Dr. Klenke[2] announced that he had cured a number of more or less intractable diseases by the galvanic introduction of medicines into the system. For struma he introduced iodide of potassium, for syphilis mercury, &c. Dr. Hassenstein[3] has likewise published an abtruse memoir on this subject; but neither Klenke nor Hassenstein have been able to satisfy the profession of the accuracy of their observations.

[1] Archives générales de Médecine, vol. ii. p. 432. Paris, 1833.
[2] Zeitschrift Wiener Aerzte, Mai 1847.
[3] Chemish-electrische Heilmethode. Leipzig, 1853.

Voltaic Narcotism.—In 1859 Dr. Richardson[1] proposed to induce anæsthesia by a combination of electricity with narcotics. For this he used Pulvermacher's chains, and a solution of equal parts of tincture of aconite and chloroform. He experimented on dogs and rabbits, and afterwards on men; and produced anæsthesia to such an extent, that severe operations could be performed with little or no pain. The expectations which were at first entertained of this new mode of inducing anæsthesia have, however, not been realised. Dr. Waller has shown that the application of a mixture of equal parts of tincture of aconite and chloroform alone produces loss of vascularity and nearly complete anæsthesia in the human skin in ten or fifteen minutes; that electricity neither retards nor accelerates this process; that the anæsthesia is limited to the spot to which the narcotising mixture is applied, and that it is caused by the local absorption of the mixture; that this absorption may produce death in animals, and might be dangerous in infants and children; and that the action of the narcotic mixture with or without electricity, when applied to the healthy skin, is followed by a severe local inflammation of an obstinate character, which would be a bad complication in surgical operations.

Dr. Richardson has since then given to the profession a far readier means of producing local anæsthesia in the ether-spray; and he has thus made ample compensation for any disappointment which may have been caused by the failure of voltaic narcotism.

XXV.—EXTRACTION OF METALLIC SUBSTANCES] FROM THE HUMAN BODY: THE ELECTRO-CHEMICAL BATH.

In 1855 M. Poey asserted, in a paper which was read before the French Academy, that it is possible to extract various metallic substances from the human body by the aid of electricity; whether they have been taken as remedies, or have become absorbed into the system of persons occupied in the different arts and trades in which their employment is required. He relates that an electro-plater, at Havana, who had frequently immersed his hands into solutions of nitrate and cyanide of gold and silver, became affected with a bad ulcer which resisted every treatment. On one occasion, while preparing a bath for electro-plating, he

[1] Medical Times and Gazette, February 12, 1859.

immersed his hands into the liquid before the object to be plated had been in it, and noticed that the negative wire became covered with a metallic coating. From this it was concluded that these deposits came from the hands of the electro-plater, who was advised by M. Poey to repeat the operation in order to extract any particles of metal which might be remaining. The result was that the ulcer was cured.

The electro-chemical bath consists of a large copper tub filled with water, and insulated from the ground; and the patient sits in the tub on a wooden seat, which is likewise insulated. For the extraction of mercury, silver, or gold, the water in the tub is acidulated with nitric or hydrochloric acid; if lead is to be extracted, sulphuric acid is added. One end of the tube is connected by means of a screw with the negative pole of a battery of thirty pairs of plates, while the positive pole is held by the patient in the right and the left hand alternately. The positive electrode is made of iron, and covered with moistened linen. The galvanic current now enters the body by one of the arms; it circulates, according to M. Poey's graphic description, everywhere, from head to foot, traverses all the internal organs, and even the bones, seizes every particle of metal which it meets on its journey, restores it to its primitive form, and deposits it on the entire surface of the sides of the tub, more especially opposite that part of the body where the metal is supposed to exist; but all this is mere hypothesis. Patients have often been said to suffer from the effects of poisonous metals in the system, but no proofs of the actual presence of such metals in the body have been forthcoming. Let a patient be put into the bath where there is no doubt about the presence of a foreign metal in the system; as, for instance, one who has become blue by the prolonged use of nitrate of silver; when such a patient has been rendered white by the bath, I shall be convinced, but not until then. The American, Eli B., who made a tour of the European hospitals ten years ago, and who was a sort of celebrity as the 'blue man,' had taken a large number of electro-chemical baths at New York, in order to get rid of the blue colour, but without the least effect; and this is, in my opinion, a strong case against the electro-chemical bath. I willingly admit that in some cases of rheumatism and allied affections the electro-chemical bath may be of service, especially when combined, as is now often done, with a local application of the current to the suffering part; but

there it does not act by extracting metals; nor can we doubt that in many cases the electro-chemical bath must be ineffective or hurtful, where a proper application of electricity to the suffering part alone might cure the patient.

XXVI.—THERAPEUTICAL USE OF ELECTRICITY IN MIDWIFERY.

Bertholon in France, Herder, Stein, and Kilian in Germany, and Drs. Radford and Barnes in this country, have recommended and used electricity in cases of tedious labour and hæmorrhage from the uterus, especially in some forms of placenta prævia; and for originating uterine contractions in cases where it is necessary to induce premature labour. As to the mode of application, Kilian has recommended applying a galvanic forceps, the blades of which consist of two different metals. Dr. Radford proposed the application of one pole of a faradic current to the abdominal parietes over the fundus uteri, and of the other to the os uteri by means of a vaginal conductor. Mr. Cleveland, on the contrary, has directed the two poles to the abdomen externally, and the same proceeding has been adopted by Dr. Barnes, while Dr. F. W. Mackenzie thought it necessary to apply the positive pole to the nape of the neck and the negative to the cervix uteri, for acting energetically upon the contractile fibre-cells of the uterus.

Professors Simpson and Scanzoni consider electricity in midwifery all but useless, and believe that when uterine action has apparently been excited by galvanism, this has been either a mere coincidence, or it has resulted from the impression made on the mind of the patient, or by mechanical irritation of the uterus or the abdominal parietes by the electrodes. Dr. F. W. Mackenzie's experiments, however, certainly show that in cases of placenteal presentation, in which profuse hæmorrhages continue to recur, notwithstanding the employment of the plug and other means, before the os is sufficiently dilated to admit of manual assistance; and in cases of hæmorrhage in the early months of pregnancy, which resist other treatment, and which from the constricted state of the os and cervix uteri do not admit either of mechanical or manual interference, faradisation is most valuable.

This is corroborated by the experience of Dr. Kühn,[1] who used

[1] Comptes rendus, October 1860.

the induced current in the case of a woman in whom, eighteen hours after delivery, the placenta had not been expelled on account of atony of the uterus. One conductor was placed to the cervix, and the other to the abdominal parietes above the uterus. The circuit had scarcely been closed when the uterus contracted and expelled the placenta.

M. de St. Germain [1] states, as the result of his researches, that in no case have uterine contractions been induced where they had not already spontaneously commenced. This explains, according to him, the discredit into which the electric current has fallen as a means of inducing premature labour. He has also found that, wherever labour pains have commenced, occurring at intervals of fifteen or twenty minutes, on the application of the conductors to the lateral parts of the abdomen, in about ten minutes a remarkable increase of the uterine contractions occurs, and that contractions so induced are much more prolonged and more painful than others. The dilatation of os uteri has constantly taken place with rapidity; and a fact to be particularly insisted upon, especially as it is not noticed by Barnes and Radford, is that the expulsion of the placenta immediately follows that of the infant, being either spontaneously projected beyond the vulva or capable of removal without the slightest traction. In two cases only the infant exhibited a slight bluish colour, but in these the cyanosis could be explained by constriction. M. de St. Germain believes that faradisation should be submitted to further investigations, and expects that it will prove chiefly useful for a rapid expulsion of the placenta.

Faradisation of the womb is unquestionably one of the most effective means at the disposal of the accoucheur for checking hæmorrhage after birth. It has likewise the advantage of being cleanly and simple in its application, and that no exposure and deluging with cold water is required. Mr. Parsons,[2] of Liverpool, has used this proceeding in a case of twin-birth, in which the patient was sinking from hæmorrhage, the uterus being large and flabby. Pressure, irritation of the womb by the hand introduced into it, and ergot, had been tried and failed. Faradisation was then resorted to, one electrode being directed to the cervix, while the other was applied to the abdominal parietes. In a few minutes slight uterine contractions occurred, and in half-an-hour

[1] Medical Times and Gazette, November 13, 1869.
[2] Medical Times and Gazette, August 26, 1865.

the womb had contracted to its proper size. The hæmorrhage was then quite arrested, and the woman made a good recovery. Dr. Mackintosh,[1] of Doncaster, has used the same means in a case in which convulsions came on during the first stage of labour, and required the use of chloroform. Failure of uterine action occurred before the os was fully dilated. Forceps delivery was found necessary, and after the placenta had been removed, the hæmorrhage from the flabby uterus could only be checked by keeping the hand in the organ. Grasping and kneeding it, cold affusion externally, injections of cold water, and perchloride of iron having failed to arrest the bleeding, faradisation was resorted to in the same manner as above. Almost immediately firm contraction took place, and no further hæmorrhage occurred. The patient made a good recovery.

Puerperal Eclampsia.—Mr. Parsons, of Islip,[2] has recorded the case of a woman who, during her seventh confinement, was taken ill with severe frequent eclamptic fits, with complete cessation of uterine contractions. He applied galvanism (faradisation) externally, with immediate effect, the bags of membrane becoming tense and protruding through the os. Within three-quarters of an hour from the commencement of the application the child was born; faradisation was again used after the placenta had been expelled, in order to ensure perfect contraction. Although there was albuminuria, the patient made a good recovery, and never had a return of the fits afterwards.

In conclusion, I will say a few words on the accidents which may be caused by an injudicious application of electricity. This powerful agent is not one of those remedies which, if they do no good, can do no harm; but on the contrary, it may, in the hands of an inexperienced operator, do a great deal of mischief. Blindness has been caused by an improper application of the continuous current to the face; fainting, spasms, hysterical fits, and palsies have been induced by administering powerful shocks; and fresh apoplectic attacks have come on in patients who had previously suffered from cerebral hæmorrhage. Accidents of this kind can only be avoided if the operator is guided by physiological knowledge and therapeutical experience. With this remedy more than with any other the mode of application has an all-important bearing upon the results; for it is not electricity that cures diseases, but the physician, who may cure diseases by means of electricity.

[1] British Medical Journal, August 6, 1873.

[2] British Medical Journal, vol. i. 1868.

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